EFFECTS OF REHABILITATION IN PATIENTS WITH CARDIAC DISEASE

ANN TAYLOR, MSc. MCSP. Dip TP.

Thesis submitted to the University of Nottingham for the degree of

Doctor of Philosophy, May 1996.

To Stewart,

without whose support and understanding this project would not have been completed.

CONTENTS

ABSTRACT

Prospective, randomised controlled trials were performed to investigate the benefits of cardiac rehabilitation in two selected patient groups. One group comprised patients in the early stage of recovery after an uncomplicated myocardial infarction. The other consisted of patients with stable chronic heart failure, who are usually excluded from exercise programmes.

The reliability and validity of a new method of measuring ambulatory activity was determined.

The rehabilitation programme for the post myocardial infarction patients lasted six weeks and contained education and exercise components. Three groups were recruited; a control group, a group who only undertook the education sessions and a group who also participated in a training programme. Comparison of changes in psycho-social parameters and physiological function were made between the groups after completing the programme and three months later. The education + exercise group showed significantly greater improvements ($p<0.05$) in anxiety, ambulatory activity and rehabilitation status compared to the other groups. Indications of predominantly peripheral adaptation to training were observed, but no significant differences in physiological function were found between the three groups. The education only group did not show any significant differences to the control group in any areas.

A crossover-design was used in the chronic heart failure study. This comprised a control and exercise period, each lasting two months. Assessments of psycho-social parameters and physiological function were made at monthly intervals. Exercise training produced significant improvements in depression, quality of life and ambulatory activity. Both

central and peripheral adaptations to training were observed, with significant benefits in peak cardiac index, oxygen uptake and resting heart rate. Improvements in ventilatory efficiency were also noted.

ACKNOWLEDGEMENTS

I am indebted to all the people in Queens Medical Centre who have helped me with this research project.

Drs Alan Cowley and David Gray were instrumental in my involvement with this study and provided guidance and support throughout the years, for which I gratefully thank them.

Without the help and support of the other members of the cardiac rehabilitation team the early rehabilitation study would not have taken place. We all learnt from each other and special thanks go to Helen and Alison for their continued support from the first meeting.

Many medical personnel have been involved with the project and have spent numerous hours supervising exercise tolerance tests for me. I would particularly like to thank Richard, John and Karen who bore the brunt of the work.

Few research projects function without technical support, and I will always remember the contributions of Maxine, Angela, Alison and Sara and the hours spent together in the exercise laboratory.

I would like to thank all the members of Cardiovascular Medicine for making my time within the department enjoyable and keeping the trials and tribulations of research in perspective. I left with less blood but happy memories.

Finally I extend my appreciation to all the patients who were involved in the project.

CHAPTER 1

INTRODUCTION

It is estimated that at least 300,000 people per annum suffer a myocardial infarction (MI) in the UK, which in 1991 resulted in 170,000 deaths across all age groups (Coronary Prevention Group 1992). This means that approximately 40% of all patients who have a MI survive.

Whilst some patients return to their former lifestyle without any problems or assistance there are others for whom the return appears daunting and unachievable in the early stages of recovery. It is to help the latter group maximise their physiological recovery that cardiac rehabilitation was developed.

The World Health Organisation has defined cardiac rehabilitation as " the sum of activities required to ensure the patients the best possible physical, mental and social conditions so that they may, by their own efforts, resume as normal a place as possible in the life of the community" (Miranda 1991).

Outline of the history of Cardiac Rehabilitation.

In the early part of the twentieth century the management of a MI patient usually involved six to eight weeks of best rest. Gradually this was reduced following the findings of Mallory et al. (1939) that scar tissue formation was usually complete by the eighth week. As further studies showed the detrimental effects of prolonged bed rest (Levine and Lowne 1952; Moss et al. 1977; Saltin et al. 1968) there was a trend to earlier mobilisation of patients. In the mid 1960s in-patient mobilisation was advocated, together with discharge of patients within a week of their MI (Certo 1985). There has been a concomitant development in organised cardiac rehabilitation programmes with the general aim of integrating the patient back to their former lifestyle. These have followed differing formats varying in duration of programme, content and time of enrolment and also the type of patient recruited if exercise was part of the programme. This variety, and the use of different end-points in studies, makes it difficult to determine the efficacy of cardiac rehabilitation and devise an optimal programme .

Whilst 74% of health districts in the UK provide cardiac rehabilitation (British Cardiac Society 1995), the programmes have generally not been subjected to formal assessment and their objectives are often unclear. This adds to the problem of determining whether cardiac rehabilitation is beneficial for patients, and if so, in what way.

There has also been some concern in the literature regarding the possible detrimental effects of early exercise on cardiac function in patients who have had an anterior MI (Jugdutt et al. 1988).

Previous Cardiac Rehabilitation at University Hospital.

Prior to 1991 University Hospital, Nottingham did not offer any formal rehabilitation for post MI patients. The number of MIs confirmed by the WHO criteria was 832 in 1985 rising to 889 in 1989. They received general advice concerning driving and return to work and were shown an audio-video cassette promoting a positive approach to returning to a normal lifestyle. In addition they were given British Heart Foundation literature, with the emphasis on the patient to ask for further information. A patient would usually be admitted onto the Coronary Care Unit and remain for 36-48 hours, being discharged from the hospital after 5 - 7 days for an uncomplicated MI, with a clinic appointment at 6 weeks.

From the literature it would appear that formal cardiac rehabilitation programmes are beneficial in returning patients to their former lifestyle and may reduce the incidence of fatal re-infarction (Oldridge et al. 1988; O'Connor et al. 1989). However there is a lack of clear consensus concerning the format, duration and timing of a programme. Consequently it was decided to implement a cardiac rehabilitation programme as part of a research project to determine its efficacy rather than introducing it directly as an in-service option.

Rehabilitation of patients with chronic heart failure.

Cardiac rehabilitation programmes which include an exercise component often exclude patients with chronic heart failure as these have been formerly considered too high a risk to undertake exercise (McKelvie et al. 1995). The second component of the research study investigated the effects of exercise in these patients as a preliminary to offering exercise therapy as an adjunct to their pharmacological management.

Development of activity level assessment.

During recent years there has been an increasing awareness that the results of formal symptom-limited exercise tests do not always reflect the functional activity level of the subject. To this end many studies now include measurements of the normal activity levels of subjects. Another part of this research project has been to develop and evaluate different methods for determining the functional activity of subjects.

Objectives of the research project.

1) To determine whether early cardiac rehabilitation has a beneficial effect on physiological and psycho-social parameters and how long any responses persist once the programme has been completed.

2) To identify the contribution of the education and exercise components of the programme and thereby devise an optimal programme.

3) To determine the effects of an exercise programme on selected physiological variables, psycho-social factors and functional activity in patients with chronic heart failure.

4) To investigate the integrated function of the the cardiovascular system in the early stages of recovery following a myocardial infarction and after a period of exercise training in patients with chronic heart failure.

5) To compare assessments of exercise tolerance by formal exercise testing with walk tests and measures of normal ambulatory activity.

PART A

EARLY REHABILITATION AFTER A MYOCARDIAL INFARCTION

CHAPTER 2

REVIEW OF THE LITERATURE

2.1. CARDIAC REHABILITATION.

General overview.

There is a plethora of literature concerning cardiac rehabilitation programmes for patients who have experienced an uncomplicated myocardial infarction. Unfortunately there is a large diversity in their content, duration, time of enrolment and type of patients recruited. The design of the studies and selection of outcome measures also varies, thus compounding the difficulty in arriving at clear conclusions concerning their efficacy.

The early studies mainly adopted a conservative approach and concentrated on programmes that often did not involve patients until two or more months post MI. It was not until the late 1970s that the effects and safety of commencing rehabilitation within the first month of recovery were investigated in an attempt to minimise the effects of deconditioning (DeBusk et al. 1979; Lerman et al. 1976; Mayou et al. 1981; Sivarajan 1982). From these beginnings studies into the effect of exercise and recovery from a MI have taken various directions. They have compared the intensity of exercise programmes; supervised and non-supervised exercise; the inclusion of different components into the programmes and the involvement of patients with impaired left ventricular function.

Tables 2.1-2.4 present a brief overview of the studies that are relevant to the development of an early cardiac rehabilitation programme.

Of those programmes, the work of Sivarajan et al (1982; 1983) and Gulanick (1991) are most closely related to the design of the present study.

The former study prescribed the exercise intensity on the basis of METs (one MET is the amount of oxygen consumed at rest and is estimated as an oxygen uptake of 3.5 ml/Kg/minute) estimated from the general population. This has problems in that it is only an approximate guide and it is difficult to determine how it relates to an individual's exercise capacity. One functional aspect that was analysed was the distance walked by the patients, but the data for this was determined from a questionnaire and so may have been influenced by the subjects recall and interpretation of distance. Gulanick included both post coronary artery bypass graft and MI patients in his study, of which the latter formed only 12.5% of the sample. Both of these studies included in-patient rehabilitation which Gulanick considered may have limited the scope for improvement in the out-patient programme due to the patients increased self-efficacy at discharge. The study of in-patient rehabilitation by Taniguchi et al. (1990) is relevant mainly due to the early exercise testing of patients. Their results were limited by the use of "dropouts" as control patients. These patients were initially incluced in the active group, and this, together with their non-compliance with the study protocol, makes them unsuitable for use as control patients.

Most of the studies presented in the tables give very little information concerning the medical and pharmacological management of the patients. The latter is important when negatively chronotropic drugs such as beta-blocking agents are withdrawn prior to an exercise test, as the heart rate achieved during the test will be higher than that obtained when the drug is resumed. This creates the situation where the patient is effectively having to work at a higher training intensity than originally intended.

Two of the studies investigating the effects of different programme components (Oldridge et al. 1991; Stern et al. 1983) involved subjects

Table 2.1 Studies of early cardiac rehabilitation.

Study	Subjects	Programme components	Exercise programme	Outcome measures
Sivarajan et al. (1982; 1983) Early exercise test. Effects of components.	n = 258 < 71 years Start as in-patient 5 days post MI.	12 week programme. 3 groups; 1) Control 2) Exercise 3) Exercise + advice	General activity at 2-3 METs. Once weekly supervised; twice daily at home.	Activity questionnaire. Exercise tolerance test. Lifestyle questionnaire.
Hung et al. (1984) Cardiac function	n = 53 men Mean age 55 Start 3 weeks post MI.	8 week programme. 2 groups; 1) Control 2) Exercise	At home. Week 1-4, 30 mins, 5 times weekly,70-85% peak heart rate.Week 5-8 at 100% peak heart rate.	Exercise tolerance test
Taniguchi et al. (1990) Anaerobic threshold.	n = 11 Mean age 60 2 weeks post MI as in-patient.	Two week in-patient exercise programme.	30 mins walking, twice daily at 90% anaerobic threshold.	Exercise tolerance test
Gulanick (1991) Phase 2 programmes.	n = 40 Mean age 58 Start 4 weeks post MI and coronary artery by-pass graft.	5 week programme. 3 groups; 1) Control 2) Advice 3) Advice + exercise.	3 times weekly. 70-80% peak heart rate.	Psycho-social questionnaire. Exercise tolerance test groups 2 and 3.

Table 2.2 Studies into the effects of different components of cardiac rehabilitation programmes.

Study	Subjects	Programme components	Exercise programme	Outcome measures
Stern et al. (1983) Counselling Vs. exercise	n = 106 men Mean age 54. Start 6 weeks-1 year post MI Clinically anxious and depressed.	12 week programme. 3 groups; 1) Control 2) Exercise 3) Counselling	3 times weekly at 85% peak heart rate.	Activity questionnaire. Exercise tolerance test.
Sivarajan et al. (1983) Advice Vs. exercise	See Table 2.1			
Oldridge et al. (1991) Exercise + counselling Vs. community rehabilitation.	n = 201 Start 6 weeks post MI Clinically depressed.	8 week programme. 2 groups; 1) Community (control) 2) Exercise and advice.	2 times weekly at 65% peak heart rate.	Psycho-social questionnaire. Exercise tolerance test.
P. Re. Cor group. (1991) Counselling Vs. exercise	n = 182 men Mean age 50 Start 1-2 months post MI.	6 week programme. 3 groups; 1) Control 2) Exercise and counselling 3) Counselling.	3 times weekly. 80% peak heart rate.	Psycho-social questionnaire. Exercise tolerance test.
Gulanick (1991) Advice Vs. exercise.	See Table 2.1			

Table 2.3 Studies into the effects of different intensities of exercise.

Study	**Subjects**	**Programme components**	**Exercise programme**	**Outcome measures.**
Paterson et al. (1979) Cardiovascular function	n = 79 men Mean age 45 Start 3-12 weeks post MI.	12 months daily exercise. 2 groups; 1) High intensity 2) Low intensity	1) HIGH - Walk / jog 65-70% peak oxygen uptake. 2) LOW - Walk / Jog 50% peak oxygen uptake.	Exercise tolerance test
Blumenthal et al. (1988) Physiological changes	n = 45 men Mean age 52 Start 8 weeks post MI.	12 week programme; 3 times weekly. 2 intensity groups; 1) High 2) Low	1) HIGH - 65-75% peak oxygen uptake. 2) LOW - <45% peak oxygen uptake.	Pedometers. Exercise tolerance test.
Goble et al (1991) Physiological changes	n = 308 men Mean age 52 3 weeks post MI.	8 week exercise programme. 2 intensity groups; 1) High 2) Low	1) HIGH - 75-85% peak heart rate; 3 times weekly. 2) LOW - Increase in heart rate less than 20 beats above resting; twice weekly.	Exercise tolerance test
Worcester et al (1993) Quality of life	n = 224 men Mean age 52 3 weeks post MI.	As above	As above	Psychological questionnaire; Quality of life interview. Exercise tolerance test

Table 2.4 Studies investigating non hospital-based exercise programmes.

Study	**Subjects**	**Programme components**	**Exercise programme**	**Outcome measures**
Miller et al (1984) Home Vs. gym DeBusk et al. (1985) Unsupervised exercise.	n = 198 men Mean age 52 Start 3 weeks post MI.	8 or 23 week programme; 3 groups in each programme; 1) Home 2) Gym 3) Control	70-80% peak heart rate; HOME - bike / walk 30 mins, 5 times weekly. GYM - 3 times weekly, 60 mins.	Functional activity. Exercise tolerance test
Bethell et al.. (1990) Community programme	n = 200 men Start 4-6 weeks post MI.	3 month programme. 2 groups; 1) Control 2) Community exercise	3 times weekly	Exercise tolerance test
Ueshima et al. (1990) Unsupervised exercise	n =183 Mean age 55	One month programme. 2 groups; 1) Control 2) Exercise	Walk/jog 90-100% anaerobic threshold for 2Km.	Psychological questionnaire. Pedometers. Exercise tolerance test.

who were diagnosed as clinically depressed which limits their generalisation to other subjects. On completion of the 8 week intervention period, 41% of the subjects in the study of Oldridge et al. (1991) were further enrolled into a conventional cardiac rehabilitation programme, thus affecting the results of the follow up period.

2.2. THE PHYSIOLOGICAL EFFECTS OF EXERCISE IN HEALTHY SUBJECTS.

The benefits derived from an aerobic exercise programme are influenced by the duration, intensity and frequency of the exercise regime, initial fitness and general activity level of the subject. In order to facilitate physiological changes healthy subjects are usually advised to exercise at intensities of between 45-70% maximum oxygen uptake, according to level of fitness and desired response, for a minimum of 20-30 minutes at least 3 times a week. The early benefits are generally those that occur as a result of changes in the trained muscles (peripheral adaptation), but with increased length and intensity of training, changes are also thought to occur within the heart itself (central adaptation).

Peripheral adaptation

Macro and microscopic changes occur within the substance of trained muscles in response to the demands of regular aerobic exercise, thus increasing their aerobic potential. These changes include an increase in capillary density to facilitate exchange of substances between the muscle fibres and the circulation; increases in mitochondrial volume and enzymes involved in aerobic metabolism; increase in myoglobin content to aid delivery of oxygen to the active muscles and an increase in the maximum blood flow through exercising muscles. Additionally, blood flow is redistributed from inactive to active muscles (Astrand and Rodahl 1986).

The overall physiological effect of these changes is increased oxygen delivery to and extraction from the blood within the active muscles. This means that for the same minute oxygen uptake the cardiac output will be reduced, thus reducing the myocardial oxygen demand. Consequently, the exercise capacity of the subject will be increased, together with an increase in maximum oxygen uptake. An increase in oxygen extraction means that for the same sub-maximal work load the blood flow/Kg of working muscle will be reduced (Astrand and Rodahl 1986; Bethell 1992).

The increase in availability of oxygen to the muscle at the same sub-maximal workload will result in a delay of the onset of the 'anaerobic threshold'. The latter is used to define the point when metabolic acidosis and associated changes in gas exchange in the lungs occurs during graded exercise (Astrand and Rodahl 1986).

The term anaerobic threshold is often used to evaluate the effects of exercise on the peripheral musculature but there is considerable debate concerning the validity and determination of this concept. Several studies (Brooks 1991; Campbell et al. 1989; Hughson et al. 1987; Yeh et al 1983) have suggested arterial lactate increases continuously in an exponential function. They consider the methodology used in other investigations (Beaver et al. 1986; Dickstein et al. 1990; Koike et al. 1992; Robergs et al 1990) have given rise to the continued acceptance of the threshold concept, especially where visual interpretation of the plots have been based on small subject numbers. These studies have themselves been criticised, and when that of Yeh et al (1983) was replicated but analysed in a different manner an aerobic threshold was identified (Wasserman et al 1990).

Central adaptation

Regular long term aerobic training increases the left ventricular end-diastolic volume whilst maintaining normal wall thickness (Astrand and Rodahl 1986; Fox and Matthews 1981). This, together with an increase in contractility, results in an increase in stroke volume which is responsible for the increased maximal cardiac output. At rest and sub-maximal loads there is a decrease in heart rate due to an increase in acetylcholine and vagal tone and a decrease in sensitivity to catecholamines, resulting in a decreased sympathetic drive (Astrand and Rodahl 1986). The reduction in drive may originate from the increase in stroke volume maintaining the required cardiac output or it may be connected with neural input from proprioceptors and the motor cortex. Consequently, the decrease in sub-maximal cardiac output initiated in the early stages of training due to increased oxygen extraction is augmented by this central adaptive mechanism. These adaptations are primarily related to the duration and frequency of exercise.

Changes in the respiratory system.

Maximum minute ventilation increases after aerobic training, partly due to an increase in maximum aerobic capacity which results in an increase in carbon dioxide production, and partly due to the higher level of lactic acid (Astrand and Rodahl 1986). At sub-maximal loads minute ventilation decreases, which is attributed to a decrease in carbon dioxide production and delayed acidosis.

Ventilatory efficiency also improves after training, as indicated by a decrease in the ventilatory equivalent for oxygen (Astrand and Rodahl 1986; Clausen 1976; Fox and Matthews 1981). The former is related to the ability of the respiratory system to facilitate gaseous exchange and is thought to be influenced by both anatomical and physiological dead space and factors regulating respiration. A decrease in the ventilatory equivalent for oxygen or carbon dioxide indicates less minute ventilation is required to supply/remove one litre of the gas from the lungs. The increase in efficiency may be attributable to improved ventilation/perfusion matching within the lungs and changes in the control of ventilation via chemoreceptors and mechanoreceptor activity in the exercising limbs.

2.3. THE PHYSIOLOGICAL EFFECTS OF EXERCISE IN PATIENTS AFTER A MYOCARDIAL INFARCTION

In the early recovery period after a MI, exercise tolerance is decreased due to myocardial damage and a period of deconditioning occurs whilst hospitalised. However, with the increased use of early thrombolysis the extent of myocardial damage is now reduced, thus presenting the patient with an increased potential to return to their former level of activity.

Peripheral adaptations similar to those seen in healthy subjects are thought to occur in this patient group (Clausen 1976; Detry et al. 1971), although there is some debate concerning the presence of central changes (Cobb et al. 1982; Ehsani 1987; Franklin et al. 1992; Hagberg 1991; Hung et al 1984). The latter may be partially attributable to the different methods used to determine changes in stroke volume.

In patients, the safety of the exercise programme has to be considered and so the intensity is generally lower than that prescribed for healthy subjects and this may limit the scope for central adaptation. However, programmes starting several months post MI often have intensities similar to those prescribed to stimulate peripheral changes in normal subjects i.e. 70-85% maximal heart rate or 55-75% maximal oxygen uptake.

Peripheral adaptation

Detry et al. (1971) and Clausen (1976) were amongst the first workers to investigate factors other than central circulatory parameters when determining the physiological changes due to training in patients with coronary artery disease.

In a small study Detry et al. found an increase in arterio-venous oxygen difference at sub-maximal loads, accompanied by decrease in cardiac output, whilst the stroke volume remained unchanged. From this they suggested that muscle blood flow was probably also decreased in response to increased oxygen extraction, although the former was not measured. A major limitation of this study was the lack of a control group and the heterogenous sample, the latter being a mix of patients with angina and re-infarction, wtih wide variations in time after infaction.

Clausen found the physiological changes were predominately peripheral, and the increase in maximal oxygen uptake was a function of increased blood flow to exercising muscles rather than central adaptation. At sub-maximal loads he found that trained muscles extracted more oxygen from blood, allowing muscle blood flow to be reduced whilst still maintaining the same sub-maximal oxygen uptake. This supported the concept that muscle blood flow per weight of muscle was a function of the relative physiological work load.

Other studies have also shown evidence of peripheral changes as a result of training, with wide ranging differences (16-56%) in improvements in maximal oxygen uptake (DeBusk et al. 1979; Hung et al. 1984; Ignone et al. 1988). The study of Ignone et al (1988) did not include a control group but did include patients with myocardial ischaemia, thereby limiting its relevance to the effects of exercise training in patients recovering from a

MI. The magnitude of improvement is influenced by pretraining fitness, age, length and type of exercise, and the time that the exercise programme started post MI. It also needs to be remembered that in the early weeks after a MI the improvement in aerobic capacity may be in response to spontaneous recovery rather than an exercise regime, so the inclusion of a control group is very important.

Central adaptation.

In a small study of high intensity exercise performed over a year, Ehsani et al. (1982) found an increase in stroke volume at rest and during exercise, and an increase in ejection fraction during exercise, indicating an improvement in left ventricular function. However there were several methodological problems concerning the selection of patients and measurements of left ventricular function which may have influenced their results.

The effects of regular, long term, high intensity exercise was also studied by Hagberg et al. (1983). Eleven post MI patients underwent one year of exercise training at a high intensity. Initially the subjects showed changes indicative of peripheral adaptation, but as the programme progressed increases in stroke volume and ejection fraction were observed, suggesting central adaptation. They concluded that to achieve central changes an exercise programme had to be undertaken for approximately one year, whilst peripheral changes were evident after six months. They recommended exercise intensities of 80% peak oxygen uptake compared to 70% for peripheral changes, and the exercise had to be performed at least 4 times a week, in contrast to 3 times a week for peripheral changes.

However, a study investigating exercise commencing within two months of a MI (Giannuzzi et al 1993) found improvements in ejection fraction not only in patients who participated in a six month training programme but also in the control group. In comparison to the two previous studies, most of these patients had received thrombolysis therapy which may have influenced the results.

2.4. EFFECTS OF BETA BLOCKADE DRUGS ON THE RESPONSE TO EXERCISE

The effects of beta-blockers on exercise response has been investigated in two ways. One involves healthy subjects exercising before and after the administration of the drug, and the other compares the responses of groups of patients with coronary artery disease who are taking beta blockers with those of control patients.

Sable et al. (1982) adopted the first approach and investigated the effects of beta-blockers at intervals during a five week exercise programme. They found that whilst the exercise performance improved, the beta-blockers attenuated the training effects. The subjects involved in the study were younger than the majority of patients who experience a MI which, together with their normal health state, limits the extrapolation of the study to patients. Rather, it indicates the maximum potential for improvements in exercise tolerance.

Several studies indicated the increase in exercise tolerance after training in patients who had coronary artery disease and were taking beta-blockers was comparable with that of healthy subjects (Ehsani et al. 1986; Froelicher et al. 1985; Gordon and Duncan 1991; Laslett et al. 1983). The exercise programmes ranged from 3 to 12 months and were generally of a high intensity. The changes seen were those of peripheral adaptation, but smaller reductions in sub-maximal heart rate were seen in patients taking beta-blockers than those not taking the drug.

It has been suggested that the effect of the training response may be influenced by the dosage and selectivity of the drug, and the presence or absence of exercise induced ischaemia (Blood and Ades 1988).

Hossack et al. (1980) found the linear relationship between increased heart rate and oxygen consumption was maintained in these patients during exercise, with r 0.86 before beta-blockade and r 0.87 afterwards. This suggests that exercise intensity can be prescribed from the results of a patient's exercise test using these two sets of values in the same way as for healthy subjects, providing medication is taken prior to the test. However, the slope of the regression line is affected by beta-blockade, and when compared to subjects who are not taking the drug, a higher heart rate is required to exercise at the same level of oxygen uptake.

2.5 PSYCHO-SOCIAL BENEFITS OF EXERCISE.

The psycho-social benefits of exercise are difficult to determine in both healthy subjects and patients with cardiac disease. This is mainly because of the lack of valid and reliable tools with which to measure changes. Regular exercise is considered to induce improvements in well-being and a decrease in depression. These are thought to be a result of changes in the neurohumoral system, but there is little evidence to substantiate this hypothesis.

Cox (1986) noted contradictory results for response to stress in trained, healthy subjects. Results ranged from no difference between trained and non-trained groups, to both lower and higher reactivity in the trained groups. In a review of the literature, Langosch (1988) did not find any conclusive evidence to suggest post MI patients who participated in an exercise programme experienced a decrease in either anxiety or depression. A few studies found short term benefits in both areas but it was difficult to ascribe these solely to the effects of exercise. These studies also generally involved subjects with clinically diagnosed depression rather than post MI apprehension, and were investigating exercise as a form of treatment for the condition.

In some programmes the objective of including exercise is to increase the patient's confidence in performing activities rather trying to achieve a training effect (Gloag 1985; Greenland and Chu 1988; Thompson 1988). In these, the type and prescription of exercise is not important and the benefits of undertaking the exercise regime is measured by improvement in quality of life rather than physiological changes.

2.6. POTENTIAL PROBLEMS OF EXERCISE

With the trend to exercise patients early after a MI and patients considered high risk for exercise, concern has been expressed regarding the safety of early exercise. Various groups have issued recommendations concerning the selection of patients, exercise testing and safety precautions (American Heart Association 1992; American College of Sports Medicine 1991; ESC working group 1993; Fletcher et al. 1990).

Animal models have been used to study the effect of exercise on the remodelling of the heart. Kloner and Kloner (1983) found evidence of thinning of the myocardial scar in rats who had undertaken a 2 week swimming regime. The difficulty with this type of study is equating the exercise regimes of animals, mainly rats, with that of people.

The influence of exercise in potentiating arrhythmia was investigated by Janosi et al. (1987). Subjects exercised at 6 weeks post MI for a unspecified length of time at a moderate intensity, whilst being monitored by telemetry. They found that the exercise did not adversely influence their heart rhythm.

Jugdutt et al. (1988) specifically investigated subjects with an anterior Q wave infarction who had not received thrombolysis. This group of patients were considered to have poorer left ventricular function than other patients. They performed 12 weeks of unsupervised callisthenic exercise, starting between 6 and 32 weeks post infarction. The intensity of the exercise was not based on individual exercise performance. Whilst their exercise tolerance increased, patients with an initial left ventricular asynergy greater than 18% experienced further deterioration. They suggested that in this group of patients exercise should be delayed until healing has occurred. However, whilst accepting the need for caution with these patients, most people would consider they applied an inappropriate exercise regime. The Exercise in Anterior Myocardial Infarction study (Giannuzzi et al. 1993) investigated similar patients to those of Jugdutt et al. but the majority had received thrombolytic therapy and each had an individually prescribed six month exercise programme. Adverse changes in left ventricular size and topography were independent of training but were related to the initial ejection fraction. They concluded that early and long-term exercise was beneficial with this group of patients if they did not show any clinical complications.

Haskell (1978) and Greenland and Chu (1988) both produced data for the occurrence of adverse events in post MI patients during exercise. Whilst these are influenced by the type of patient, commencement and intensity of exercise, Greenland and Chu stated that a cardiac arrest occurred every

111,996 patient-hours, a re-infarction every 293,990 hours and a fatality every 783,972 hours. Haskell found complications occurred every 26,175 hours in the form of either cardiac arrest (32,593 hours) or re-infarction (232,809 hours). He suggested adequate warm up and cool down periods reduced the complication rate, as this was the time when most of the complications arose.

No clinical complications have been reported after a period of exercise training, although most studies only followed-up patients for 6 to 12 months after completing the programmes.

2.7. EXERCISE PRESCRIPTION.

Borg Rate of Perceived Exertion.

Most programmes used heart rate to control the intensity of the exercise session, although a few used the Borg Rate of Perceived Exertion. This is a 15 point scale ranging from a score of 6 (very, very light) to 20 (very, very hard). The numerical scale relates to the heart rate multiplied by 10 for healthy middle aged men at specific levels of perceived exercise intensities (O'Sullivan 1984). Level 12-13 on the 15 point scale is considered to equate with 60% maximal heart rate and used in early exercise, with intensities of level 13-15 used in the later stages of recovery. Whilst the Borg scale has been used successfully as a method of monitoring exercise with healthy subjects (Williams and Eston 1989), studies have suggested it is unsuitable to be used in isolation with cardiac patients as it has a poor reliability, high intra-subject variability, and the relationship between heart rate and rate of perceived exertion is affected by beta blockers (Dunbar et al. 1992; Hellerstein and Franklin 1984; Noble 1982; Smutok et al. 1980).

METs activity scale.

When general activity rather than an exercise programme is prescribed for home use the intensity may be based on METs. This is an activity orientated system rather than a response focused prescription. Tables for the MET values of different activities are available and patients are advised when to attempt different activities. This is suitable for general advice but is not sufficiently precise for use in a progressive exercise programme and does not take into account the influence of minor changes in health state or the environment which may affect exercise performance. Additionally, unless the patient undergoes an exercise tolerance test the value of 3.5 mls O_2/Kg/min uptake at rest is an estimation, rather than a measurement, of the patients basal state.

Predicted maximum heart rate.

The other main method for regulating the intensity of exercise without undertaking an exercise tolerance test is to use a percentage of age predicted maximum heart rate, based on the formula [220-age]. This method is unsuitable if the patient is taking a chronotrophic drug, i.e. beta-blocker. The predicted maximum heart rate has a standard deviation of ten in the healthy population which would be unacceptable for use with cardiac patients, especially in the early stages of their recovery or those considered a high risk. Despite these problems this form of prescription has been used in studies (Hung et al. 1984; Thow and Newton 1990).

Measured peak heart rate and oxygen consumption.

If patients undergo an exercise test prior to participating in a training programme their exercise intensity can be related to their performance during the test. The results that are most commonly utilised are peak oxygen uptake and heart rate, and the onset of anaerobic threshold. A heart rate corresponding to 90% anaerobic threshold has been used (Coplan et al. 1986; Taniguchi et al. 1990; Ueshima et al. 1990) but, as previously discussed, there are many problems in determining anaerobic threshold. The advantages of this method are thought to lie with the avoidance of inducing hormonal based ischaemic events (Coplan et al. 1986).

The Karvonen method of determining a target heart rate utilises the difference between resting and maximal heart rates and gives a target heart range (American College of Sports Medicine 1991). This method has not been generally adopted in rehabilitation programmes.

The most frequently used forms of exercise prescription are those based on peak heart rate (DeBusk et al. 1979; van Dixhoorn et al. 1990; Goble et al. 1991; Gulanick 1991; Oldridge et al. 1991; Roman et al. 1983) and oxygen uptake (Blumenthal et al. 1988; Ehsani et al. 1982; Hagberg et al. 1983).

A problem common to both types of prescription are that the responses are exercise specific and the same intensity cannot be used for exercises involving different muscle groups, such as arm and leg activity, or different types of activity, for example dynamic and static exercise. When a percentage of oxygen uptake is used this can be converted to a target heart rate by a linear regression model utilising the patients own data. The use of the patients own data is important, because as discussed in section 2.4, the slope of the gradient is altered by beta-blockers and use of values determined from healthy subjects will underestimate the target training heart rate.

CHAPTER 3

IMPLEMENTED CARDIAC REHABILITATION PROGRAMME

The American College of Cardiology (Parmley 1986) recommended the following goals for cardiac rehabilitation programmes;

1. To return the patient to optimal physiological and psychological function.
2. To reverse the adverse effects of physiological deconditioning resulting from a sedentary lifestyle which is accelerated by bed rest.
3. To introduce the patient and their family to a lifestyle that may reduce the risk of coronary heart disease.
4. To assist the patient to return to activities that were important to the quality of their life prior to their MI.
5. To reduce the emotional disorders frequently accompanying serious health disorders.

In order to achieve these goals, cardiac rehabilitation is often described as having several stages according to the timing and objectives of the programme. Phases 1 and 2 have the short term objectives of increasing functional exercise, and providing health education and psychological support to the patient and family. Phases 3 and 4 have longer term objectives, with a view to modifying risk factors, improving fitness levels, often beyond the pre-MI state, and encouraging the pursuit of active leisure activities (Gattiker et al. 1992).

Phase 1 incorporates the period of hospitalisation with the emphasis on low level exercise, advice and counselling. Phase 2 follows on at an out-patient stage and often includes supervised exercise sessions together with exercise tolerance tests to monitor the recovery of the patient through the programme. This phase may commence within days of discharge from the ward or may be delayed for several weeks or months. Most hospital based programmes only include these 2 phases, with the remaining 2 generally based within the community. The third phase usually encompasses a progressive exercise regime which continues for a further 9-12 months after which it changes to a maintenance programme (phase 4) with annual evaluations (Squires et al. 1990).

Development of the programme.

The main factors that determined the form of the University Hospital cardiac rehabilitation programme were the philosophy of interested personnel, review of the literature and the logistics of implementing and evaluating the programme.

From the literature it was evident that most programmes contained elements of education, information, advice, counselling and exercise. A multi-disciplinary team was often involved with representatives from the medical, nursing and rehabilitation professions. In the UK most programmes were based within a hospital setting, although a few were community based.

From initial meetings with Cardiology Consultants, staff of the Coronary Care Unit and rehabilitation professions, a team consisting of nurses, occupational therapists and a physiotherapist emerged who would be responsible for designing and implementing the programme. For the first 3 years the programme was to be run as a research study thus allowing it to be evaluated before any decision was made regarding its implementation as an in-service provision.

An informal, unstructured form of phase 1 in-patient rehabilitation was already in operation, and whilst it was acknowledged as requiring further development and evaluation, it was felt that the study should concentrate on a phase 2 programme. All the interested parties agreed that the programme should start soon after the patient had left hospital, as feedback from patients had identified this as a vulnerable and anxious time for them and their families.

"The period between discharge and the first clinic appointment seemed an endless time during which uncertainty, ignorance, fear and anxiety loomed ever more insistent" - quote from a patient.

Additionally, it is still relatively unusual to begin rehabilitation programmes earlier than a month after a MI and its benefits have not been fully assessed. Most of the previous studies were conducted prior to the general use of thrombolysis and at a stage when the management of these patients precipitated deconditioning due to enforced inactivity.

The underlying philosophy of the cardiac rehabilitation team was the programme was intended to assist patients and their families to return as far as possible to their normal activity levels, and provide psychological support.

The reason for encouraging partners to attend was that several studies (Cay 1982; Derenowski 1991; Hentinen 1986; Riegel and Dracup 1992; Stern 1984) reported that both patients and partners experienced varying degrees of emotional upset during the recovery period and this was often the main factor influencing return to normal.

It was felt that a programme started soon after discharge from hospital went some way to re-integrating the patient, but it should not be of such a duration that the participants became dependent on the programme and the team. If the programme was effective it should minimise the need for a prolonged programme which may inhibit progression to independence.

In order to achieve the aim of reintegration a combined programme of education, information, advice, counselling and exercise was considered. This would allow the contribution of each component to be assessed as well as evaluating the programme as a whole. A 6 week programme was thought to be of sufficient length to allow the education component to be discussed at an appropriate depth at weekly sessions of approximately 1 hour and for participation in an exercise programme. On completion of the programme at 8 weeks post MI those patients who were previously in work would be considering returning to work and the need for a rehabilitation programme would diminish. For those who felt they would benefit from further psycho-social support a cardiac rehabilitation support group was available in Nottingham, whose role is primarily that of continued social support.

Selection of education component.

The selection of topics to be discussed created the greatest debate. Prior to the implementation of the rehabilitation programme patients had requested advice from various medical personnel on how they could attempt to reduce the risk of re-infarction, consequently it was felt this area needed to be included within the education programme to minimise patients receiving conflicting and confusing advice. However, the topic of risk modification is highly contentious with only limited evidence that secondary prevention is effective. After discussion with cardiologists, it was decided to include a session on what were considered to be probable risk factors but to avoid dogma.

Discussions on new information that may have appeared in the media were to be encouraged and the findings placed in the context of the patients' general medical management and lifestyle.

Most of the remaining education components also stemmed from questions asked by patients during their recovery period. These ranged from guidance on when to resume specific activities, to explaining the effects of different drugs and medical terminology. The literature identified that patients and their families often experienced anxiety at various stages of their recovery and so it was thought to be beneficial to include sessions on recognising stress and how to manage it.

<u>The six week programme.</u>

1. Leisure, pleasure and work.

   Advice on returning to previous activities, with modifications where necessary.

2 & 3. Recognition and management of stress (2 sessions).

   Recognition of physical, psychological and emotional features of stress and their effect on a person. Suggestions for adopting coping strategies.

4. Coronary artery disease and management

   Explanation of patho-physiology of coronary artery disease; medical terminology and management; general discussion on potential risk factors.

5. Medication

   Discussion of different types of drugs and their effect; possible side-effects .

6. Healthy eating

   Promotion of a positive attitude to diet and avoidance of a restrictive regime unless advised by medical personnel.

The cardiac rehabilitation team of coronary care nurses, physiotherapist and occupational therapists would lead the sessions, with a dietician presenting the sixth session. The advantage of the team members leading the sessions rather than bringing in other specialists was considered to be that the patients would feel more able to ask questions and discuss problems if they saw the same personnel at each meeting. If specialist information was required the team would be able to contact a relevant person to provide the patient with the information at the next meeting. A medical social worker who was involved with the post MI patients on the ward asked to be included on an 'ad hoc' basis.

Selection of the exercise programme.

The selection of the exercise component took into consideration the early nature of the programme, type of patient, studies on the intensity of the exercise, logistics of attending the hospital and the form of evaluating the physiological outcome of the study.

Aerobic exercise was chosen because of its effects on the cardiovascular system .

The literature demonstrated that a programme of low intensity aerobic exercise produced results similar to that of higher intensity, and there did not appear to be any safety problems associated with unsupervised exercise at home. Therefore a programme of low intensity aerobic exercise was chosen with the view to increasing the intensity as time progressed. This was thought to facilitate patient compliance, allow the programme to be performed safely at home and produce training effects similar to those of a higher intensity programme.

Choice of exercise.

The exercises were performed 3 times a week at hospital and the patients were encouraged to perform a similar programme at home on the non-attendance days. The exercise sessions were centred around a static cycle ergometer and step-ups. These were chosen because of their aerobic nature, ease of accomplishment, and lower limb activity and were suitable for use at home.

In addition to their dominant functional activity, leg exercises were chosen in preference to arm exercises because treadmill walking was used to evaluate any physiological changes, therefore the muscles being trained needed to be those that were tested. Upper limb and resistive exercises were also included if the patient's daily activity involved similar actions.

Monitoring.

The intensity of the exercise was monitored by taking the radial pulse. This procedure is not without problems (Thow et al. 1987). Various types of electronic equipment are available to monitor exercising pulse rates, such as a chest-borne transmitter and a receiver worn on a wrist band. These were considered for the supervised exercise sessions but they have limitations of use near other monitors and would not be available for home use. In the supervised sessions the radial pulse was taken by the researcher to minimise the time delay but the patient was shown how to take their own pulse at home. If they experienced difficulty in taking their radial pulse they were shown how to locate the carotid pulse. The pulse rate at rest was taken over a full minute to maximise accuracy, whilst that taken during and immediately after cessation of exercise was taken over ten seconds in order to minimise the effects of deceleration in heart rate. If a patient complained of symptoms suggesting an arrhythmia when attending for an exercise session they were connected to telemetry and their electrocardiogram (ECG) observed during the session. This had the advantage of observing the presence of any abnormality and reassuring the patient.

Before each exercise session the patient's resting blood pressure and heart rate were taken as a safety precaution and used to modify the exercise session if necessary. In addition to taking the pulse rate during and after each exercise component, a Borg score of Rate of Perceived Exertion was also taken at the end of the exercise. This, together with the exercising pulse rate, was used to increase the duration of each exercise.

Intensity and progression.

Each patient was prescribed their own individual exercise programme which was progressed in duration and intensity during the 6 week period.

For the first 2 weeks the patient exercised at a target heart rate equivalent to 40% of their peak oxygen uptake (ml/Kg/min.) on their initial exercise tolerance test. This was progressed to 45% for the third and fourth weeks based on the exercise tolerance test at 2 weeks into the programme, and 50% for the fifth and sixth week based on the exercise tolerance test at 4 weeks. The target heart rate was determined by linear regression using the oxygen uptake and heart rate data obtained at minute intervals during the exercise tolerance test. Correlations of r 0.87 to r 0.99 were found between these two measures.

The length of time for which each patient exercised was influenced by their initial fitness, age and response to the exercise.

Each session began with 'warm up' callisthenics to gradually stimulate the cardiovascular system and was concluded with a 'cool-down' period to allow the cardiovascular system to readjust to the cessation of exercise. This is particularly important as the electrical irritability of the myocardium is known to increase for a short duration after exercise.

The training sessions were performed in a room adjacent to the Coronary Care Unit with which it had a direct alarm-call system. Resuscitation equipment was situated in the room at all times.

During the first few sessions the patients exercised for only short periods at their target heart rate and rested between exercises. This ranged from 10-15 minutes exercise at their first visit but progressed to 30-40 minutes with minimal rest between change of activity according to the patients capability. The intensity of the cycling was increased by raising the resistance of the load whilst maintaining the same pedalling rate. The intensity of the step-ups were progressed by either increasing the height of the step or increasing the speed of exercise.

To ensure maximum safety and minimise competition between participants no more than two patients were exercised at any one time.

The majority of the patients had access to an exercise bike at home and followed the same programme, including performing step-ups on their staircase or doorstep. When an exercise bike was not available they performed step-ups for longer periods.

Having implemented the programme it was found to comply with most of the recommendations suggested by Horgan et al. (1992), published a year later.

CHAPTER 4

METHODS OF INVESTIGATION

4.1 SELECTION OF PATIENTS AND DESIGN OF STUDY

Selection of patients

Patients eligible for the study were those who were admitted to the University Hospital Coronary Care Unit or medical wards with a proven first MI.

The diagnosis was based on:-

A rise of cardiac enzymes creatine kinase (CK) and lactate dehydrogenase (LDH) above twice the normal maximum value;

ECG changes indicative of a recent MI;

History of chest pain.

Men and women aged between 40-75 years and capable of performing a symptom-limited exercise tolerance test between 5-10 days post MI were recruited. Informed, written consent was obtained and patients continued to take their routine medication.

Patients were specifically excluded if they demonstrated the following clinical features:

a) ventricular arrhythmia complicating a MI
b) heart failure
c) valvular dysfunction
d) non-cardiac disease limiting exercise performance
e) post-infarction angina not responding to GTN
f) taking cardiovascular related drugs other than beta-blockers and GTN.

Recruitment occurred over a 30 month period. Of 1034 patients assessed for their suitability, 128 (12.4%) complied with the entry criteria. The main reasons for excluding 906 patients were; outside the age range (24%); non-cardiac limitations of exercise i.e. orthopaedic; respiratory conditions (20.3%); re-infarction (16.5%); prescribed other drugs (14.3%) and development heart failure or other complications (10.4%). Several patients demonstrated multiple reasons for being excluded. For the first 12 months of this study there was competition to recruit patients from another research group which excluded a further 11% of subjects. A total of 78 patients agreed to enter the study (7.5% of total MI population; 60.9% of those eligible for inclusion) but 24 were withdrawn before entering the rehabilitation study. The reasons for withdrawal were changes in their medication (8 patients); inability to satisfactorily use the equipment (4 patients) and laboratory problems preventing the performance of their pre-entry exercise tests within the permitted time window (12 patients). This left 54 to start the rehabilitation programme (5.2% of the total MI population, 42.2% of those eligible for inclusion). Of these, 5 patients did not perform their follow up exercise test at 5 months post MI due to changes in their medication (2 control and exercise patients, and 1 education patient).

The characteristics of the patients involved in the study are shown in Table 4.1.

Design of the study

Subjects were randomly allocated at entry to one of the 3 study groups. The order of randomisation was determined by a random number table and administered by sealed envelopes. Due to the novel nature of the study there were no previous data available on which to base the sample size for

Table 4.1. Patient characteristics for early cardiac rehabilitation study. (95% CI = 95% confidence interval)

	Control	**Education only**	**Exercise & education**
No. of subjects	n=18	n=18	n=18
Age; mean	56.4	57.9	57.5
(95% CI)	(52.9 to 59.7)	(53.1 to 61.9)	(53.9 to 61.1)
Site of MI			
Anterior	8	7	6
Inferior	9	10	10
Lateral	1	0	1
Posterior	0	1	1
Q waves	16	15	15
Sex Female	1	2	4
Male	17	16	14
Thrombolysis	17	16	16
CK (units/L)	1944	2115	2143
Mean (95% CI)	(1446 to 2442)	(1376 to 2854)	(1388 to 2898)
Beta- blockade	16	17	17

statistical power calculations for any of the measured parameters. It was also difficult to predict the criteria for clinical significance as previous studies have shown a poor relationship between improvements in formal tests of exercise tolerance, quality of life and functional activity (Cowley et al. 1991; Guyatt et al. 1985; Lipkin et al. 1986; Walsh et al. 1995).

Of the 54 patients who entered the study, 36 participated in the cardiac rehabilitation programme and the remaining 18 acted as controls, receiving present routine care. The patients who entered the programme were randomised into 2 groups, those who received the educational component and those who additionally performed the exercise programme. Figure 4.1. outlines the design of the study.

The study was approved by the hospital Ethics Committee.

Evaluation procedure

An holistic approach to evaluating the outcome of the rehabilitation programmes was adopted, incorporating the physiological and psycho-social responses of the patients. This was based on a) literature indicating that changes may occur in all three areas b) experiences of previous studies within this exercise laboratory which suggested that physiological changes may be independent of changes in the other two areas and vice-versa.

Measurements of exercise tolerance and limb blood flow were made at entry, on completion of the intervention period (week 6) and 12 weeks later (week 18). Additional measurements of exercise tolerance were made in the two active groups at weeks 2 and 4.

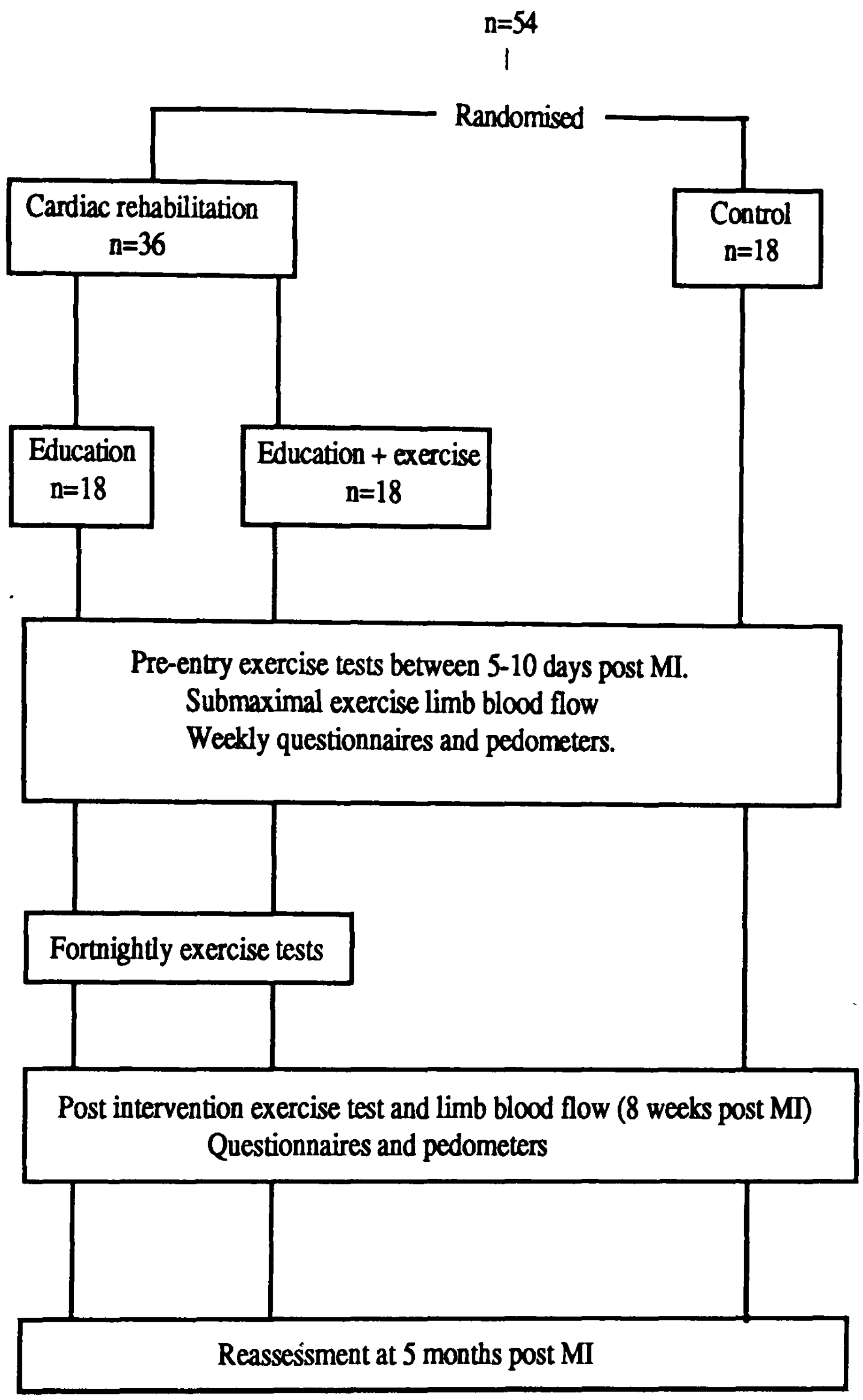


Figure 4.1 Design of the early cardiac rehabilitation study.

Psycho-social function was assessed weekly in all patients during the 6 week intervention period and at week 18.

Preliminary investigations were necessary to establish the most appropriate form of measuring cardiovascular physiology in the early period of recovery after a MI and the selection of measuring tools for determining changes in psycho-social function.

4.2 MEASUREMENTS OF PSYCHO-SOCIAL PARAMETERS

Preliminary investigations were necessary to develop a suitable questionnaire to determine the recovery of the patients during their daily lives and an objective method for quantifying their level of activity.

For this it was decided to use two questionnaires, one concerned with the psychological aspects of recovery and the other with the social functioning of the patient. This decision was taken in view of the considered effect of exercise on psychological well-being, which was discussed in Chapter 2.5, in addition to improvements physical performance. In order to examine the former effects in more detail a separate questionnaire assessing psychological change was considered to be useful.

The Hospital Anxiety and Depression Scale (Zigmond and Snaith 1983) was considered suitable to measure psychological changes but the selection of the questionnaire to measure functional changes posed problems. Many of these types of questionnaire assume the patient will not return to their former quality of life.

4.2.1 SELECTION OF QUESTIONNAIRE TO ASSESS RETURN TO FUNCTION

INTRODUCTION

Quality of life is an important aspect of recovery for patients surviving a MI. The aim of any rehabilitation programme is to return a patient to the optimal level of function which includes psychological and social, as well as physical function. Wenger et al. (1984) identified three areas which contributed to the quality of life; a) function, b) perception and c) symptoms and consequences. Researchers have experienced difficulty in combining these various aspects into one questionnaire, and where this has been attempted the result is often unwieldy and time consuming .

Most of the available questionnaires are not disease-specific measures, which has the advantage that the results can be compared for different patient groups. However, if only one specific group is being investigated it often means that many of the scales and levels of the questionnaire are not applicable to that group, particularly those with less disabling conditions. In using a general scale, Kaplan (1985) considered the transition between health states over a period of time would not be detected. This may be overcome by using a combination of a general questionnaire and disease specific measures at the expense of increased time and administration. A more acceptable solution would be to use a questionnaire designed for use with a specific condition which would yield a more precise description of the impact of the condition. At present most of the disease-specific questionnaires relate to patients with cancer and respiratory diseases and very few exist for use with patients recovering from a MI.

The reliability and validity of existing questionnaires has been questioned and may be exacerbated by professional concepts of well-being. Bowling

(1991) stated that evidence from studies comparing the responses from doctors and patients suggest that doctors cannot adequately measure a patient's quality of life. Consequently this is not a suitable method to determine the criterion validity of a questionnaire. It also suggests the need for using self-administered questionnaires whenever practicable. Concurrent validity is difficult to determine in the absence of an accepted 'criterion' questionnaire with which to compare results.

The reliability of most questionnaires is determined by the test-retest method and examination of the correlation coefficient. The disadvantages of the test-retest method is that completion of the first questionnaire may influence the response to the second, and changes, real or perceived, may occur between the two administrations. This is a particular problem in the investigation of acute conditions such as MI. Bland and Altman (1986) highlighted the problem of using correlation coefficients in determining the reliability of a measurement procedure. Unfortunately most of the present questionnaires were designed prior to the publication of their method of determining agreement between measures and consequently depend on correlations to ascertain the reliability and concurrent validity of a new questionnaire. The investigators often do not discuss what they consider to be an acceptable level of correlation.

Review of questionnaires.

The questionnaires which were considered for measurement of functional activity were the Sickness Impact Profile; Nottingham Health Profile ; Edinburgh Rehabilitation Status Scale; and the Karnofsky Performance Status Scale. In addition, disease-specific measures questionnaires developed for use with similar patients were also considered (Lindskog and Sivarajan 1982; West and Evans 1986; Wiklund et al. 1984; Wood-Dauphine et al. 1988).

Disease-specific measures questionnaires.

Lindskog and Sivarajan (1982) developed an activity summary questionnaire for use in a study similar to the proposed early rehabilitation programme. The objective of the authors was to provide a questionnaire that was "pertinent to patients recovering from MI; suitable for both men and women, and short and simple to encourage compliance". It consisted of 16 questions with the responses requiring information concerning the quantity of the activity performed during a day and over a week. This would provide useful data for a longitudinal study. A test-retest reliability study was not performed as it was considered the condition of the patients did not remain on one level long enough to allow multiple assessment. The inter-rater agreement for the questionnaire was found to be greater than 83% but no further analysis was performed. The concurrent validity was determined by comparing the physical responses of the subjects with their responses to the questionnaire. The questionnaire differentiated between differences in physical attributes of groups, but only had a weak correlation (r -0.31; $p<0.001$) between functional aerobic impairment and distance walked.

West and Evans (1986) designed a questionnaire to investigate long term changes in post MI patients. This comprised of 13 questions which required a Yes or No response with further quantification to any positive reply. The questions focused on smoking, diet, weight, exercise and psychological aspects of recovery. This questionnaire may be useful in assessing the outcome of some of the aspects discussed in the education component of the rehabilitation programme. The validity and reliability of the questionnaire have not been reported.

The questionnaire developed by Wiklund et al. (1984) included several useful areas but many of the questions were too culturally sensitive for use in the Nottingham study group.

The Re-integration to Normal Living Index (Wood-Dauphine et al. 1988) is concerned with the general well-being of the patient and aspects of it may be applicable, although details of the questions are not available. During its development the ratings of the subject, "significant others" and medical professionals were compared. The highest correlation was found between the patients and significant others (r 0.6), with weak correlations for patients and professionals (r 0.38 to 0.43).

General questionnaires.

The Sickness Impact Profile (SIP) is a widely used questionnaire which assesses sickness-related dysfunction. It may be self-administered or scored by an interviewer and contains 136 items encompassing 12 categories with 4 to 23 response levels. The validity and reliability of the questionnaire is considered to be good across patient groups but it takes 20-30 minutes to complete and is repetitious . The questions are negatively phrased and relate to subjects who consider themselves to be ill. It has been suggested that sections can be used independently (Bowling 1991). The SIP was used by Ott et al. (1983) in a study similar to the early rehabilitation design. Their experience highlighted the problems of using a broad spectrum questionnaire. The total median score for the questionnaire was below 5% for each study group (100%=high impact; 0%=no impact), with a cluster of scores at zero. Thus longitudinal changes between the groups were difficult to detect using this questionnaire.

The Nottingham Health Profile (Hunt et al. 1986) is a self-administered questionnaire which determines symptomatic evidence of illness and its effects on activities of daily living. It is divided into 2 sections and all the questions require a Yes or No response. The first section contains 7 questions concerned with the accomplishment of a range of activities and the second section asks questions relating to the signs of ill-health. It has been validated on a wide range of patient groups and ages and the reliability by test-retest has been found to range from r = 0.64 to 0.89. The authors acknowledge several limitations of the questionnaire; it is most applicable to patients in severe situations; the simple response level may miss improvements in longitudinal studies and it focuses on the negative aspects of health. No studies have been found where the Nottingham Health Profile (NHP) has been used with post MI patients.

The Edinburgh Rehabilitation Status Scale (ERSS; Affleck et al. 1988) was developed specifically to assess the outcome of rehabilitation. It is observer-rated and has been used across a range of conditions including cardiac disease. It has 4 sections, each with multiple levels, concerned with dependency, activity, social and symptoms. A significant correlation ($p < 0.001$) was found for the inter-rater reliability for the total scores.

A more basic questionnaire is the Karnofsky Performance Status. This is a brief interviewer-rated, 10 level scale for rating activity performance, ranging from normal to moribund. It is widely used with cancer patients on whom the validity and reliability has been based. One study (Brezinsky et al. 1991) used the questionnaire with MI patients but not to differentiate between intervention or response to treatment.

METHODS OF INVESTIGATION

From this review a set of criteria was determined to help identify the most applicable functional questionnaire:

i) Self-administered.

ii) Appropriate subscales and levels for subjects with minimal to moderate disability.

iii) Easy to complete.

iv) Suitable for either sex and range of ages.

v) Not culturally sensitive.

vi) Validity and reliability tested on a similar sample.

Justification for criteria;-

a) Self administration was selected for ease of administration and avoidance of rater bias due to non-blind nature of study. Previous work has suggested patients were more accurate in identifying their level of function than an observer.

b) The subscales and levels of response need to be relevant to the patients to avoid time being unnecessarily spent reading a lengthy document containing inappropriate questions.

c) The questions need to be relevant to both sexes and phrased to avoid sex bias i.e inclusion of domestic work as well as paid employment. They also need to be applicable to retired and unemployed subjects.

d) Self-administration of the questionnaire necessitates the questions and phraseology being understood by the subjects without further explanation.

The questionnaire forms part of the overall evaluation of the subject and not the only means of assessing their response to the intervention.

Therefore it was decided to use a questionnaire that had been previously validated on a similar subject group rather than construct one, which would have been a lengthy procedure.

Table 4.2 identifies the questionnaires which were considered to fulfil most of the criteria.

Table 4.2. Comparison of four questionnaires for fulfilment of the selection criteria.

	SELECTION CRITERIA					
	i	**ii**	**iii**	**iv**	**v**	**vi**
SIP	√	-	√	√	√	-
NHP	√	-	√	√	√	-
Activity summary	√	√	√	√	-	√/-
ERSS	-	√	√	√	√	√/-

As none of the questionnaires successfully met all the criteria, the final choice was determined by considering the weight of influence of each component of the criterion.

A feature common to all of the questionnaires was the lack or limited information concerning reliability and validity of the questionnaires when applied to post MI patients. This was of concern in deciding whether to continue to utilise this method of measuring functional activity. If the questionnaire were the only method of assessing possible changes in functional activity the potential problems concerning the reliability and validity of the questionnaires would render them unsuitable. However, it was to be used in conjunction with data gained from pedometers concerning ambulatory activity.

The length, inappropriateness of levels and negative phraseology of the questions outweighed the established acceptability of the SIP.

The NHP was eliminated due to its generality, lack of levels and non-use with a similar patient group.

a) Activity Summary Questionnaire

The activity summary questionnaire (Lindskog and Sivarajan, 1982) appeared to be an appropriate questionnaire for use in this study. It had been developed specifically for a similar population group and used in a comparable study with no reported problems. The disadvantages of the questionnaire were an absence of data concerning its reliability and the limited investigation of its validity. In order to determine its suitability for the study this questionnaire was administered to 10 patients with modifications to the American terminology (see appendix A for a copy of the questionnaire).

Results of Activity Summary Questionnaire

The main problems encountered by patients were centered around the difficulty in determining the amount of detail required for some questions. This caused incomplete answers for many of the questions, which in turn created problems in scoring the questionnaire.

Conclusion

On the basis of this preliminary investigation the questionnaire was considered unsuitable for this study due to the difficulty of the patients interpreting the questions, leading to incomplete information.

b) Edinburgh Rehabilitation Status Scale

The ERSS was considered to fulfil most of the criteria but it is an observer-rated questionnaire and in its original form (see appendix B) was considered to contain too many inappropriate levels for each subscale. After consultation with Professor Youngman, Department of Education, University of Nottingham, it was decided that modifying the questionnaire by altering the levels of the subscales rather than the questions would have a minimal affect on the validity and reliability of the questionnaire.

This created a questionnaire which contained 4 questions and 4 levels of response which were directly relevant to the subject and was quick and simple to complete (see appendix C).

To investigate the suitability of this questionnaire for self-administration rather than observer rating, the modified form was administered to 32 pairs of subjects (patient and partner) with the patients possessing similar characteristics to those of the proposed study. The pairs of subjects were instructed not to confer whilst completing the questionnaire and were observed during this time to ensure compliance. The pairs of results for each section and the total score were compared.

Results of ERSS

The section which had the largest number of equal scores between patients and partners was for the presence of symptoms (78% agreement). In the support section 67% of the scores were the same compared to 60% for the activity and 56% for the social sections.

As previous studies used tests of correlation to validate questionnaires, a Spearman rank correlation test was performed to compare the results of the two sets of scores (see Table 4.3).

Table 4.3. Comparison of Spearman rank correlation (r_S) for results of patient and partner for modified ERSS questionnaire.

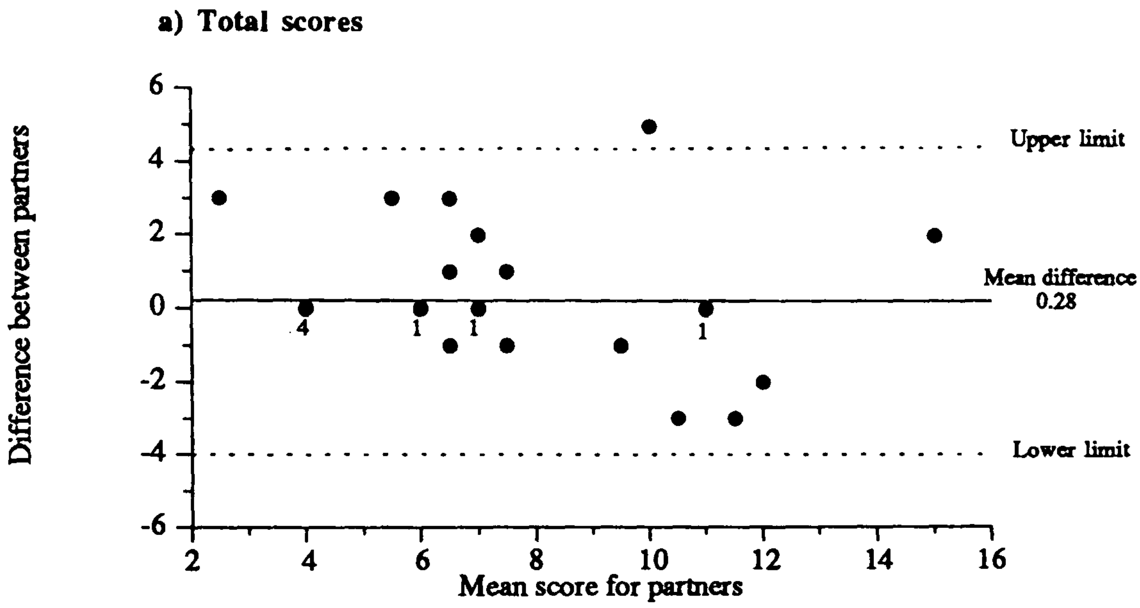
n = 64	Total scores	Question A Support	Question B Activity	Question C Social	Question D Symptoms
r_S	0.82	0.62	0.54	0.76	0.85
p	<0.0001	<0.0001	<0.001	<0.0001	<0.0001

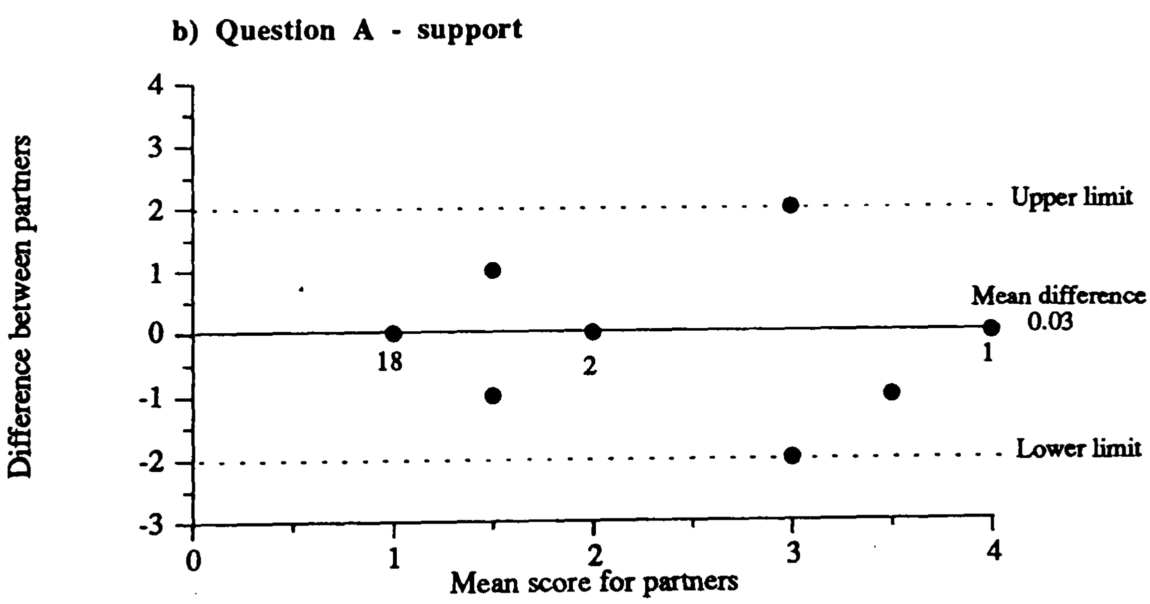
The high correlation of responses between patient and partner for all the questions and total score indicated a strong linear relationship between observed and self-rated scores. It has been suggested that this method provides misleadingly high correlation coefficients because a high linear relationship would be expected between the two sets of data and it does not reflect the amount of agreement between the measurements. The 'limits of agreement' method by Bland and Altman (1986) provides greater insight into the agreement between 2 sets of data and was applied to the responses from patient and partner. The difference between the sets of scores were determined and plotted against the mean of the two scores (see Figures 4.2 a-e). A negative value indicates the patient had a higher score than the partner and the patient perceived a greater restriction on their lifestyle than their partner did.

Discussion

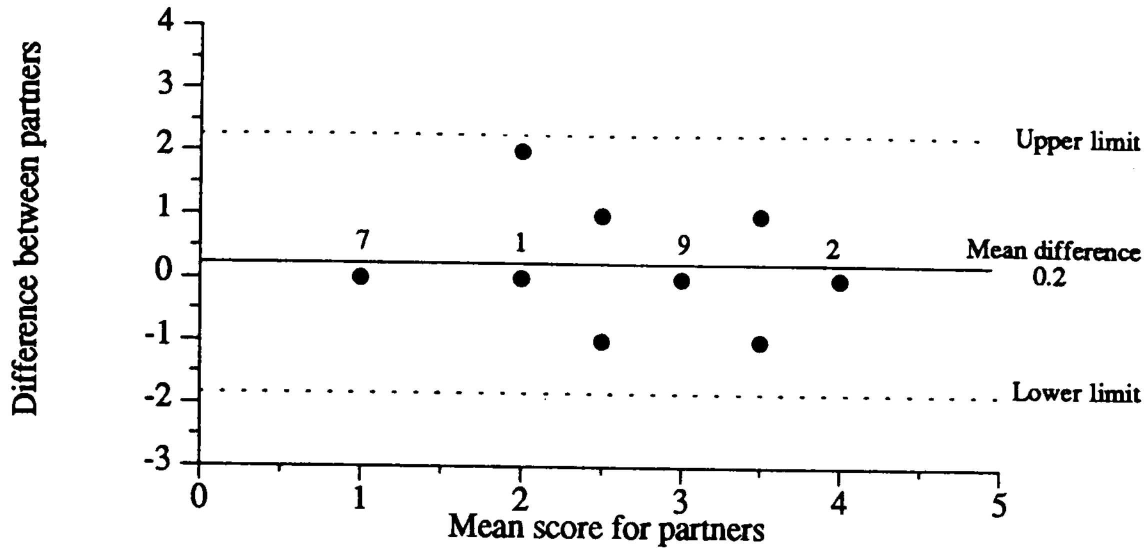
Figures 4.2 a-e, identified sections where there was some disagreement between the scores and showed the difference tended to increase as the scores increased, i.e. when the patients lifestyle appeared to be more affected by their condition. In sections A, B and C (support, activity and social) the limits of agreement for the scores were ± 2 points, suggesting a wide difference between the perception of patient and partner concerning

Figure 4.2. Limits of agreement between partners for ERSS scores.
(Numbers indicate occasions when partners gave same score).

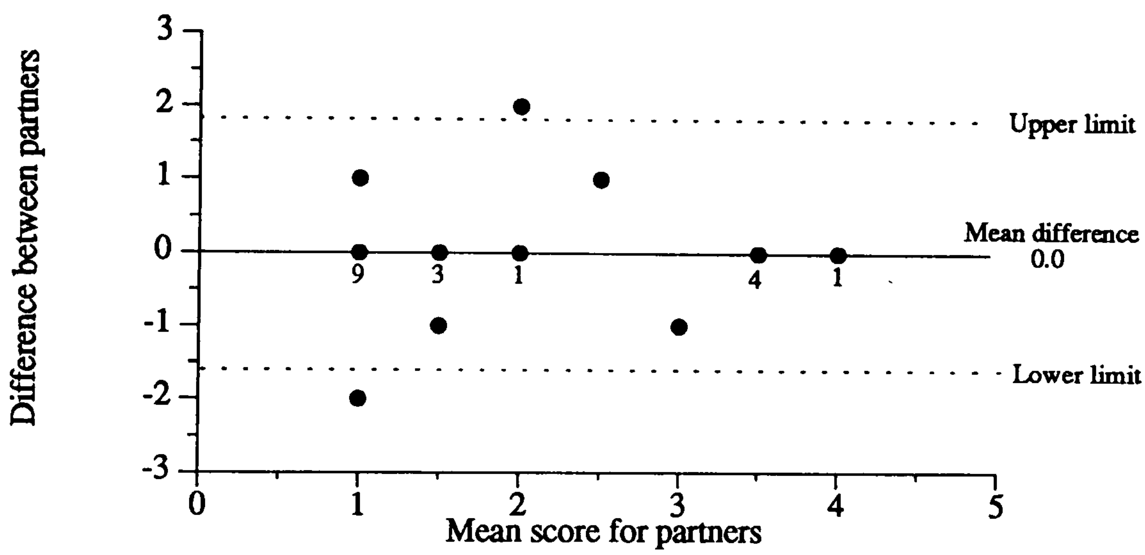




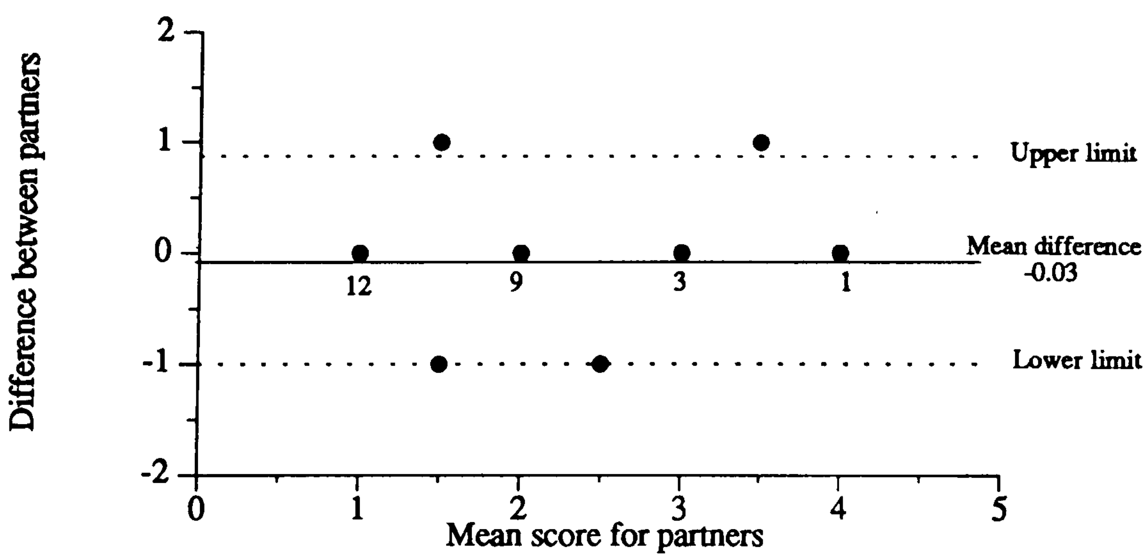
c) Question B - activity



d) Question C - social



e) Question D - symptoms



those aspects of the patients lifestyle. However, for the majority there was no difference between the pairs of data and only 12.5% of the scores were outside ± 1 score. In section D (symptoms), the limits of agreement were ± 1 point, with 78% of the scores the same for both patient and partner.

The lack of agreement between the pairs of scores may be a reflection of only using four levels of response in each section. This allows small subjective differences of one level to assume a large numerical difference between responses. The use of more levels may result in a smaller magnitude of variability between scores and increase its sensitivity to changes, but would also increase the complexity of the questionnaire and its time for completion. However the correlation coefficients were generally higher than those found by Wood-Dauphine et al. (1988) between 'significant others' and patients.

None of the respondents experienced any difficulty in interpreting the questionnaire and whilst the magnitude of the limits of agreement give some cause for concern over a small range of scores, the general closeness of the pair of scores suggest that the questionnaire is suitable for self-administration. If the validity of its use as a self-administered questionnaire were determined by correlation ratios as in other studies, it would be considered a highly acceptable questionnaire.

CONCLUSION

The modified ERSS questionnaire appeared to be suitable for self-administration and fulfilled the criteria required for a questionnaire in this study. The patients did not experience any problems in completing the questionnaire, consequently it was considered suitable for use with this group of patients.

4.2.2. VALIDITY AND RELIABILITY OF MECHANICAL PEDOMETERS.

Pedometers have been used as a simple, convenient and objective measurement of changes in ambulatory activity levels in many studies (Bertie et al. 1992; Cowley et al. 1991; Patrick et al 1986; Rozkovec et al. 1989). Most pedometers and are designed to be worn on a waistband or belt and record the distance travelled in kilometres or miles. They function as an accelerometer and are triggered by the vertical displacement of the wearer's hip during walking which causes a pendulum to move through a pre-determined arc of movement relative to the case (see Figure 4.3). The distance moved by the pendulum is converted into units in the display window. In order to accommodate different lengths of stride, the amplitude of the arc can be adjusted. The larger the stride setting, the greater the range of the arc and the number of units recorded per step.

Initial observation suggested several factors could influence the accuracy of the recorded distance. First, the stride length of a subject may not remain constant over the period the pedometer is worn. This is apparent when comparing stride lengths between indoor and outdoor walking, and it may also alter as a result of changes in health state. Second, the acceleration of the vertical displacement of the hip varies between individuals and on occasions within subjects. The normal range is between 0.5 ms^{-2} to 8 ms^{-2} (Cavagna and Margaria 1966). A pedometer worn by a person with a high acceleration i.e. a 'bouncy' gait, is liable to over-estimate the distance walked due to 'rebound' effects of the pendulum. These errors may be compounded by extraneous pendular movement due to trunk movements and unintentional interference with the control settings.

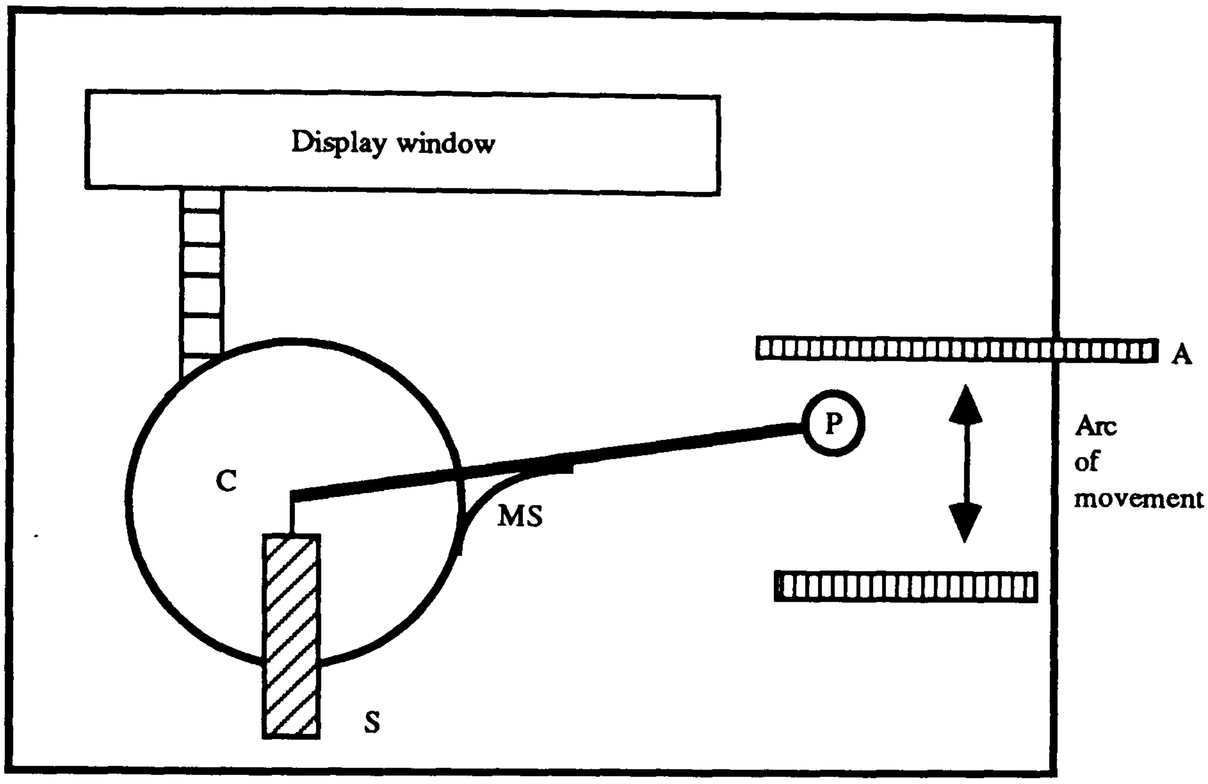


Figure 4.3. Mechanism of a mechanical pedometer.
The moveable stride adjust lever (A) determines the size of the arc through which the pendulum (P) moves. As the pendulum moves downwards a thin metal strip (MS) drives a cogged wheel (C) to record a score in the display window. A spring (S) returns the pendulum to its resting position.

Before using a pedometer as a measure of ambulatory activity the magnitude of these potential sources of error, and the accuracy and reliability of this type of pedometer, was determined.

The objectives of the investigations were to;-

a) determine the consistency of the pedometers and the influence of vertical acceleration on the scores at different stride settings;
b) investigate the validity and reliability of the pedometers when used to determine the level of activity
c) to determine a code of practice to maximise the accuracy of the pedometers for use in the study.

An investigation into the validity and reliability of the Pinion pedometer

INTRODUCTION

This mechanical pedometer is rectangular and measures 4.5cm wide, 6cm in height and 2cm in depth. It clips onto a waistabnd or belt and records a maximum of 99.9 miles, measured to the nearest 0.05 unit. The stride length setting can be varied between 2' and 5'.

In using this type of pedometer variation in stride length of subjects is a critical problem. If the stride setting is too small the true walking distance may be over-estimated, as the pendulum reaches the end of its swing with sufficient momentum to produce a rebound movement which is recorded as an independent score. Too large a stride setting will under-estimate activities because of incomplete pendulum movements.

This problem was overcome by converting the distance measured by the pedometer into footfall. This required the pedometer to be moved through a known number of steps and a calibration factor determined for the ratio of distance to steps. Using this, the displayed units could then be converted into footfalls. Consequently the stride setting of the pedometer is no longer dependent on the stride of the subject. This latter aspect was utilised in overcoming the problem of the influence of the 'bounciness' of the subjects stride on the recorded scores. The stride setting could now be set at an optimal length suitable for all the subjects.

The remainder of the investigation focused on determining the optimal stride setting of the pedometer.

METHODS OF INVESTIGATION

a) Assessment of the consistency of the pedometer and the influence of acceleration on the calibration factor at different stride length settings

Method

The calibration procedure involved moving the pedometers through a pre-set vertical distance for 3000 cycles on a calibration rig. The rig consisted of a shelf connected to a motor via a crank arm. The position of the arm could be altered to vary the distance through which the shelf was moved whilst keeping the frequency constant. This allowed the pedometers to be exposed to 4 different accelerations of vertical displacement (3.56 ms^{-2}; 6.98 ms^{-2}; 10.47 ms^{-2}; 13.89 ms^{-2}). Unfortunately the influence of low rates of acceleration which were within normal range could not be investigated. A calibration factor was determined by dividing the pedometer scores by the known number of 'steps' thereby identifying how many units 1 'step' signified.

Ten Pinion pedometers were tested at stride settings of 2', 3', 4' and 5' each pedometer underwent 10 repetitions at each of the 4 accelerations.

A Friedman test was used to detect any significant changes in the calibration factors at each stride setting across the four different accelerations. Where differences were found a Wilcoxon signed-ranks test with a Bonferroni correction was applied to identify which accelerations were responsible for the changes.

Results

The calibration factor was influenced by changes in vertical acceleration at all four stride lengths (see Figure 4.4), the former generally increasing with increased acceleration.

The Friedman test indicated significant differences between calibration factors across the four different accelerations at each stride setting ($p < 0.05$). Table 4.4 shows that when the accelerations most relevant to normal walking ($3.56 ms^{-2}$, $6.98 ms^{-2}$, $10.47 ms^{-2}$) were inspected closely, using a Wilcoxon signed-ranks test with a Bonferroni correction, the 2' stride was least affected by the changes and the 5' stride was the only one to be affected across all three accelerations.

The variability in scores across 10 repetitions at each acceleration are shown in Figures 4.5 a-d and expressed as the maximum percentage difference between the repetitions for each pedometer. The scores appeared to be more stable at 4' and 5' and at the lower rates of accelerations, whilst the changes were independent of specific pedometers.

Conclusion

The lack of stability of the calibration factor over the different accelerations for all the stride settings has implications if the subject's gait changes and may lead to both over and underscoring, making it difficult to determine the acceleration on the calibration rig at which to calculate the calibration ratio.

This investigation did not identify a clear advantage for selecting a specific stride setting and so three strides were selected for examination at the next stage, 2', 3' and 4'. The 5' stride was rejected at this stage due to the changing influence of acceleration on the scores.

Figure 4.4 Stability of calibration factor for Pinion pedometers at 4 stride settings and accelerations.

Median and 95% Confidence Interval for 10 repetitions.

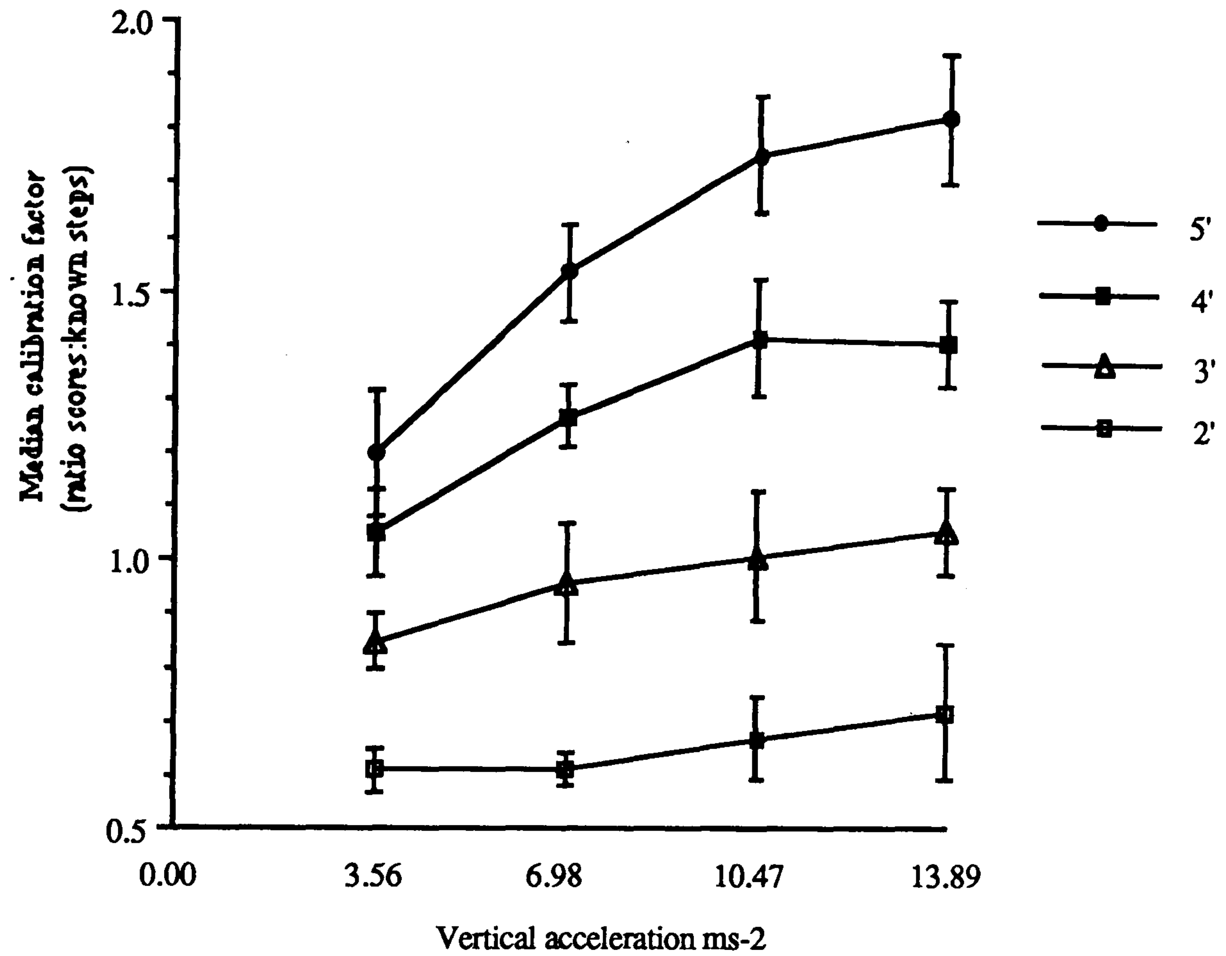
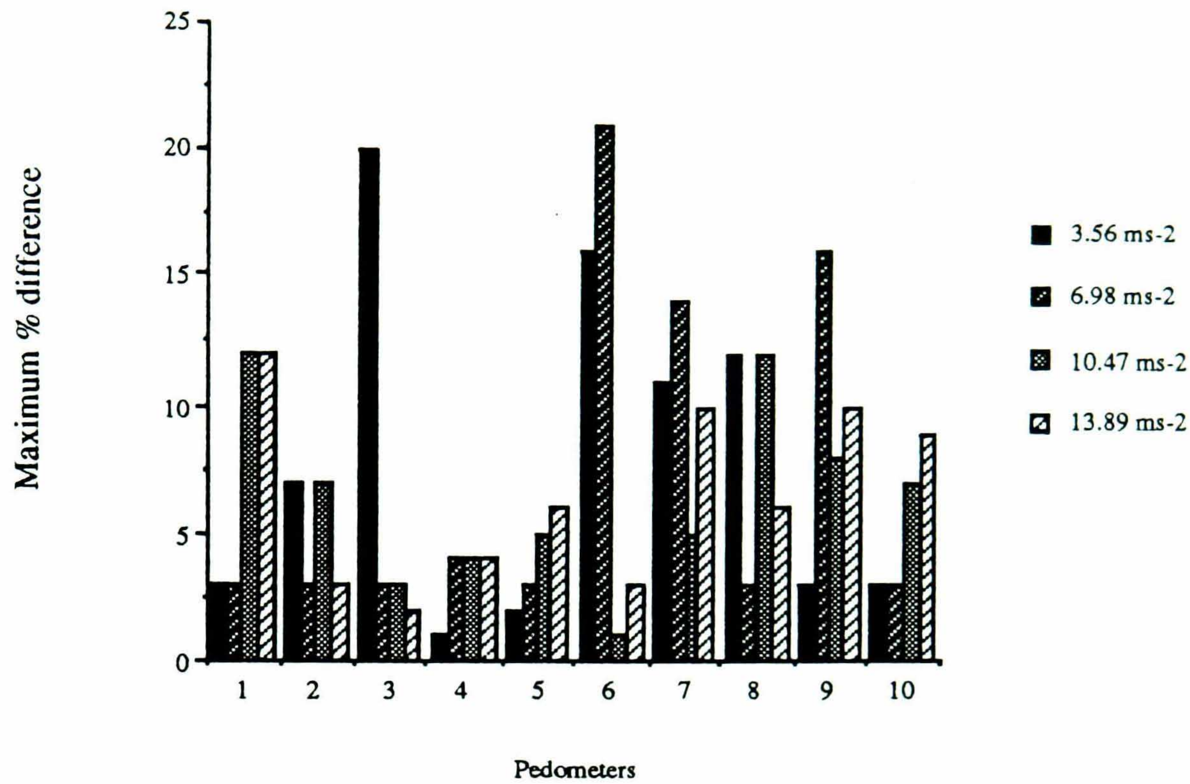


Table 4.4 Wilcoxon signed-ranks test was used to determine the influence of changes between different accelerations on the mean calibration factor for 10 Pinion pedometers.

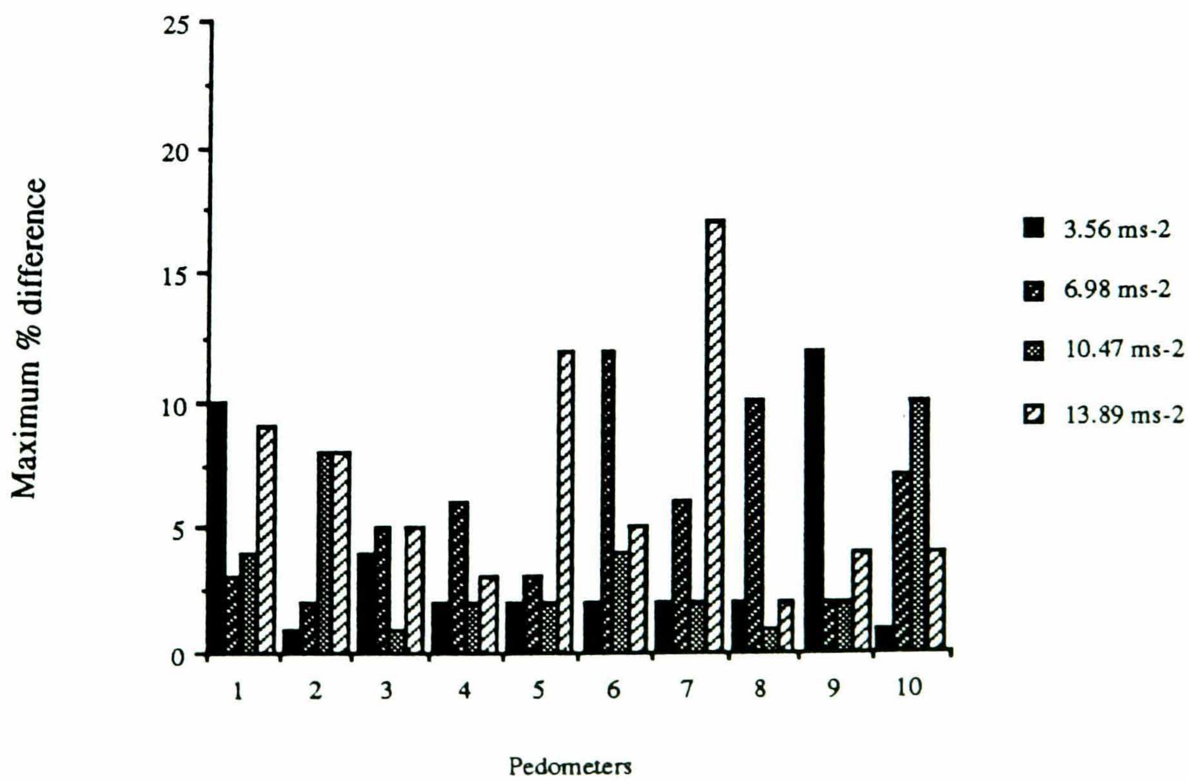
		Pedometer stride setting							
		2' stride		3' stride		4' stride		5' stride	
Acceleration ms^{-2}		**3.56**	**6.98**	**3.56**	**6.98**	**3.56**	**6.98**	**3.56**	**6.98**
6.98ms^{-2}	p =	0.85		0.02		0.02		0.02	
10.47ms^{-2}	p =	0.09	0.04	0.02	0.26	0.02	0.11	0.02	0.02

Figure 4.5 The variability in scores for 10 Pinion pedometers after 10 successive repetitions of 3000 steps.

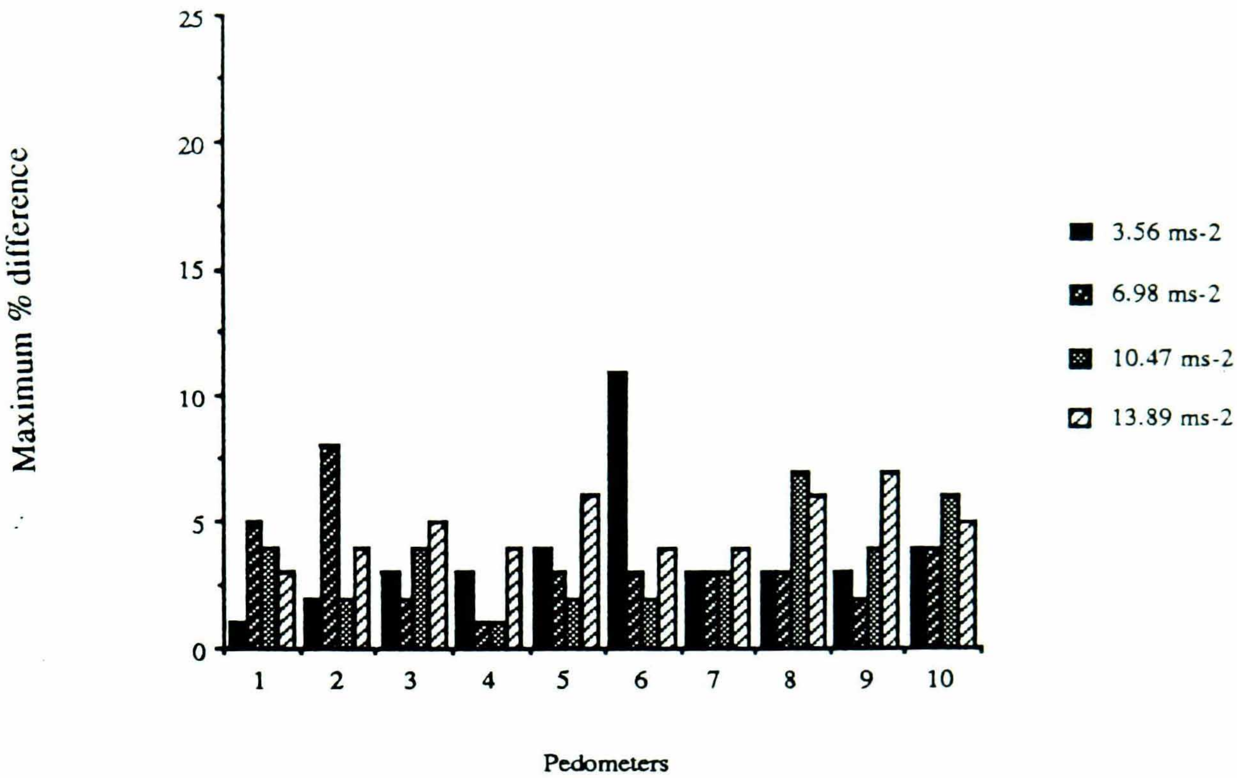
a) 2' stride setting



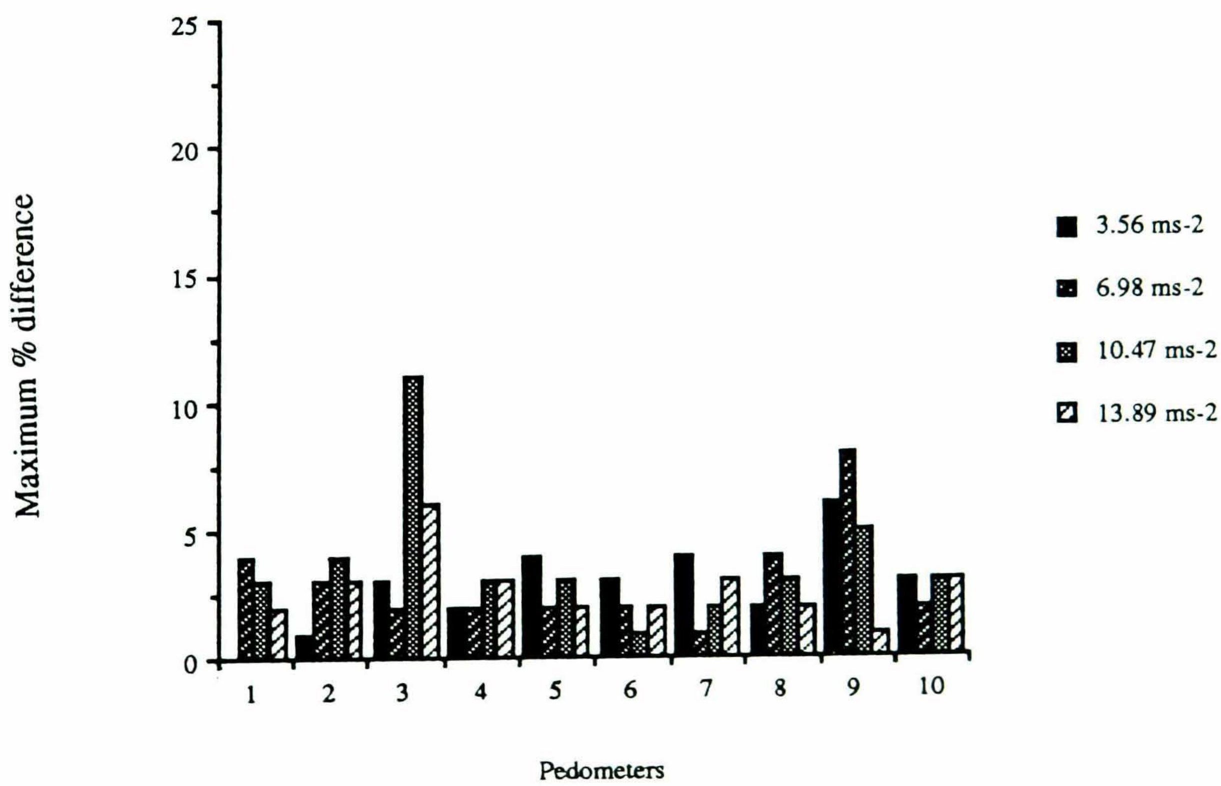
b) 3' stride setting.



c) 4' stride setting.



d) 5' stride setting.



b) Assessment of the validity and reliability of the pedometer when used to measure number of footfalls.

Method

The calibration factor was determined at $3.56ms^{-2}$ both before and after each walk and the mean value was used for the conversion of scores to footfalls.

In order to control the conditions under which these aspects were investigated, healthy subjects walked on a treadmill at a self-selected steady pace, thus providing an optimal environment for replicating continuous walking at a constant, comfortable stride length.

The first test involved a healthy subject performing ten walks of 6000 steps on a treadmill whilst wearing two pedometers over each hip. The pedometers were positioned either side of the trouser crease in accordancewith the recommendations of the manufacturer, and the outer and inner pairs were set at two different stride lengths thus enabling the scores to be compared under identical conditions. The walks were completed within five days.

A pilot study had shown that the pedometers behaved similarly irrespective of whether they were the inner or outer pair. The treadmill speed was set at 4 Kph and the subject recorded the number of steps taken using a hand operated mechanical counter. The accuracy of mechanical counting over this number of steps had been previously determined at ± 5 steps over a 60 minute walk. A pair of pedometers were worn for each stride setting to detect any malfunction in either of the pair. The mean values of both the outer and inner pairs of pedometers were compared.

To determine whether these results were applicable to other subjects, a further 8 healthy subjects each performed two walks of between 5-6000 steps at a comfortable pace whilst wearing two pairs of pedometers. The method was the same as that described above, and the second walks were performed within 48 hours of the first walk.

The same pedometers were worn by all subjects.

Results for repeated walks by the same subject

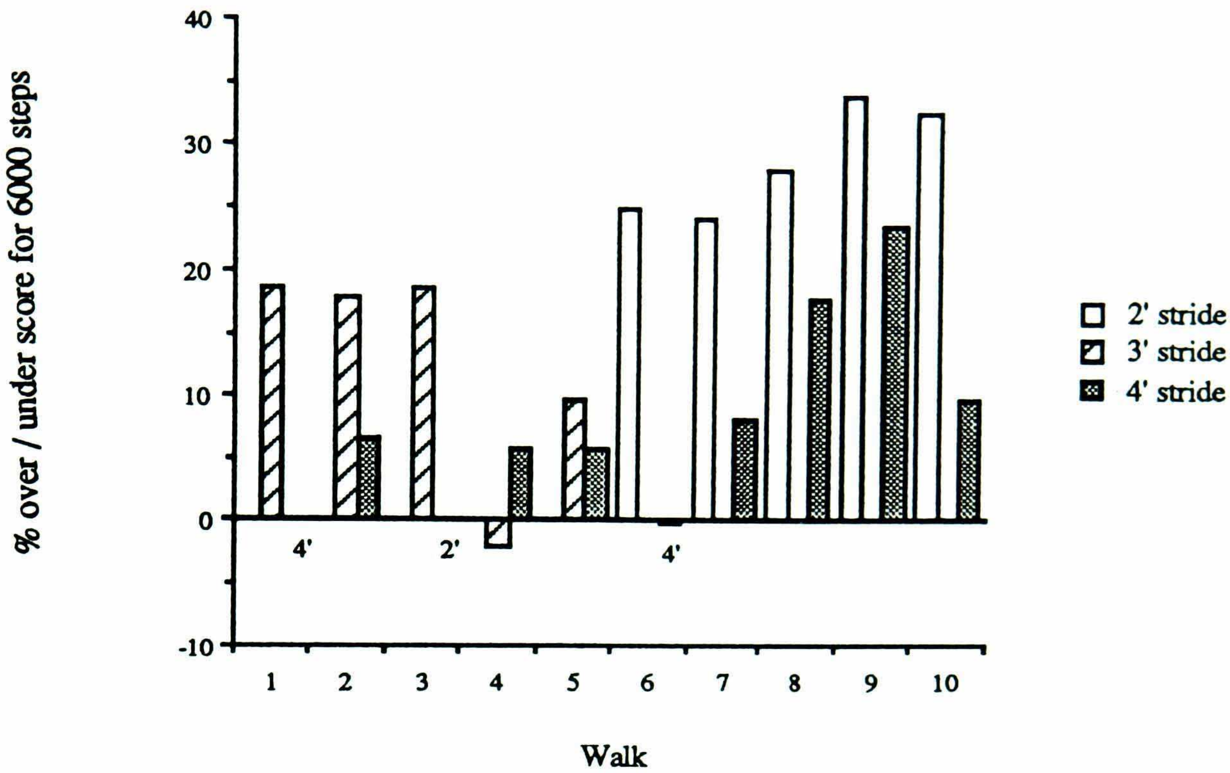
Figure 4.6a shows the scores of the hip pedometers relative to counted steps when worn by the same subject for 10 walks.

The pedometers predominantly overscored with respect to the number of counted steps. This was greatest at the 2' setting but a similar magnitude for 3' and 4' (mean overscore 28.8% [95% CI 26.7 to 30.9] at 2'; 11.8% [1.9 to 21.7] at 3', 7.3% [2.5 to 12.1] at 4'). The influence of the side of the body on which the pedometer was worn is shown in Figure 4.6b. The percentage difference between the two sides is expressed in relation to the side with the highest score. When the scores of both pairs were increased on the same side it probably indicated an asymmetry of gait. However on five walks there was a discrepancy between the two pairs as to which side of the body gave higher scores, suggesting random error or pedometer malfunction were influencing the results.

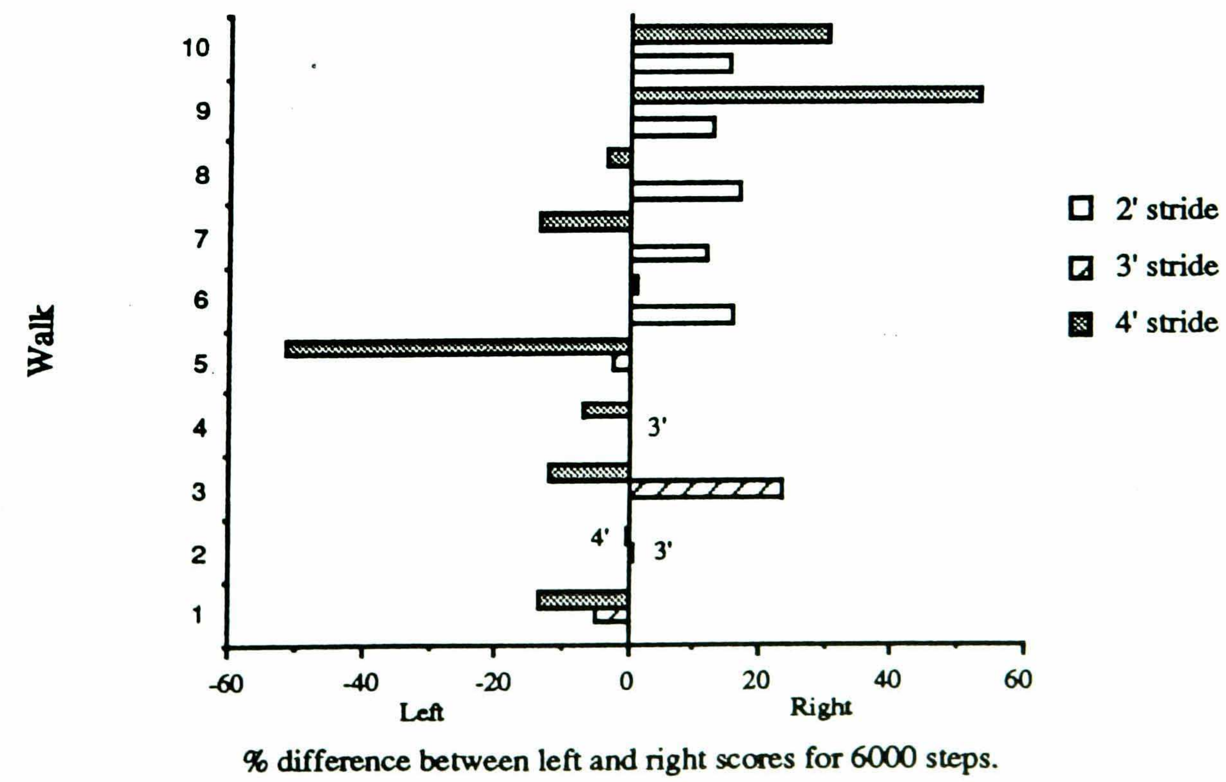
Conclusion

From this, stride settings of 3' and 4' were selected for use with the other 8 subjects as these scores were closer to the actual number of steps than the 2' setting.

Figure 4.6 a) Scores from Pinion pedometer on repeated treadmill walks by same subject using different stride settings.



b) Differences between left and right scores for same treadmill walks with respect to the highest score.



Results of pairs of walks from 8 subjects

A similar pattern of results were obtained from these subjects (see Figure 4.7a). The overscoring was greatest for 3' (mean overscore 22.4% [95% CI 15.1 to 29.7] v. 11.8% [5.4 to 18.2]) and on 4 occasions one pair of pedometers indicated an overscore whilst the other pair showed an underscore. This was only consistent across the repeated walks for 1 subject (subject 6) suggesting in this subject it was due to the different stride settings whilst in the other 2 subjects it was probably attributable to pedometer malfunction.

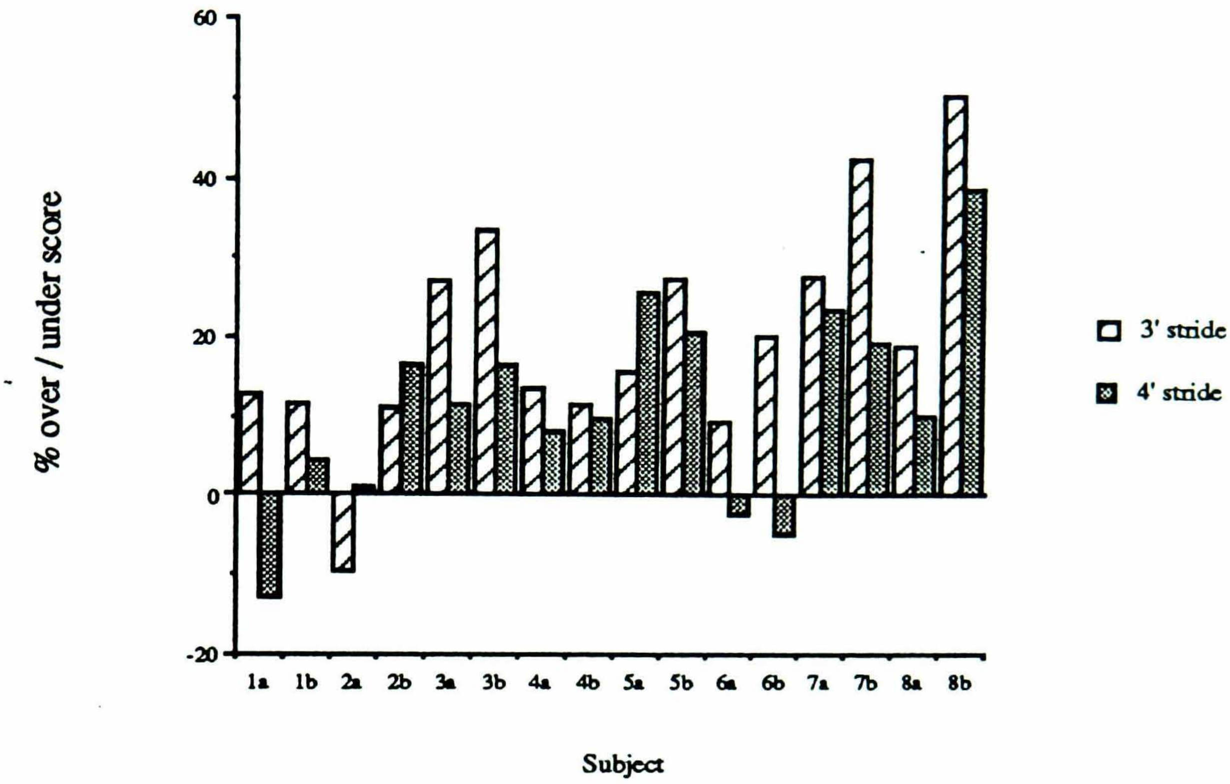
The coefficient of repeatability for the 8 pairs of walks was 57.9% at 3' and 58.2% at 4'. Again the pedometers appeared to detect asymmetry of gait (see Figure 4.7b) but in several subjects the difference in scores between right and left sides changed on the repeat walk, and on 4 occasions there was a difference between the pair of pedometers on the same walk as to which side gave the higher scores.

DISCUSSION

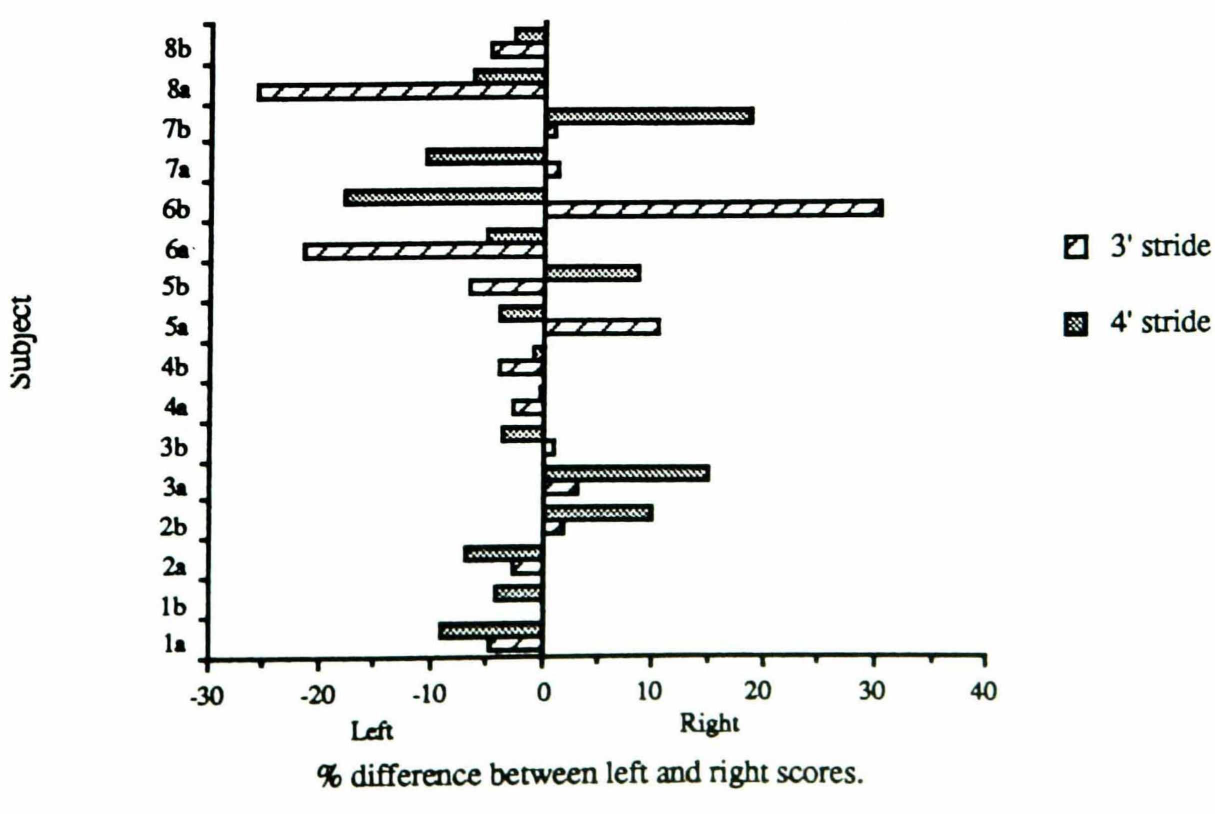
The results of this investigation show that this brand of pedometer is prone to errors which could lead to misrepresentation of the subjects ambulatory activity.

From the results of the first part of the investigation, the calibration factor for the pedometers was seen to be acceleration-dependent, so that changes in a subject's gait might influence the 'walking distance' recorded. This may be a particular problem when the pedometers are used to gain serial measurements over a prolonged period of time, especially if the subject's health altered within that time period, with a concomitant change in gait.

Figure 4.7 a) Scores from Pinion pedometers on repeated walks by 8 healthy subjects.



b) Difference between right and left scores with respect to the highest score for repeated walks.



Spontaneous changes in the scores over successive repetitions on the rig highlighted the need for regular calibration checks and wearing a pair of pedometers to facilitate detecting these changes. The precaution of ensuring a subject wears the same pedometer for repeated measurements will not overcome this problem with these pedometers, as the magnitude of the changes varied across different accelerations within the same pedometer. As the changes were independent of individual pedometers, each pedometer needs to be calibrated individually before and after use.

The results of the second part of the investigation in attempting to identify the optimal stride setting were equivocal. Whilst it does not simulate the forces of normal walking, walking on a treadmill provided an optimal environment in which to examine the reliability of pedometers. Under these conditions, the stride setting which appeared to give scores closest to those counted for most of the subjects was 4', but there was still a wide variation in scores and poor reliability.

In conclusion, the validity and reliability of this brand of pedometer appeared to be subject dependent and consequently it was not considered suitable for use as a research tool.

An investigation of the validity and reliabilty of the Digimax pedometer

INTRODUCTION

After the investigation of the Pinion pedometer another brand of mechanical pedometer was subjected to the same investigative procedure to determine its suitability as a measuring tool. It is sold as 'Digimax' (manufactured by Yamax) and measures up to 99.9 miles in 0.05 units and allows a stride lengths of between 2' and a 'maximum' (estimated as 3.5').

It is rectangular in shape and measures 3.5 cm wide, 3 cm in length and 1.2 cm deep. It operates as an accelerometer in the same way as that described at the beginning of section 4.4.2.

METHOD OF INVESTIGATION

a) Assessment of the consistency of the pedometers and the influence of acceleration on the calibration factor at different stride length settings.

The method used to assess the Digimax pedometer is as described for the Pinion pedometer, using stride settings of 2', 3' and 'maximum'.

Results

These pedometers were less affected by changes in acceleration than the Pinion pedometer as shown in Figure 4.8, where the changes in slope are smaller than before. However, a Friedman test indicated significant differences between calibration factors across the 4 different accelerations at both 3' and 2' stride settings . The scores for the maximum setting were not significantly affected. Over 10 repetitions the stability of the pedometer scores was greatest at the 3' stride setting and varied most at 2' (median 5% [95% CI 0 to 10] at 2'; 3% [0 to 12] at 3'; 4% [0 to 11] at 'maximum'). Generally the range of differences between successive repetitions was least at the higher accelerations and independent of specific pedometers (see Figures 4.9 a-c).

Conclusion

Due to the lack of effect of changes in acceleration on the pedometer scores at the 'maximum' stride, this setting was chosen for further investigation in the next stage.

Figure 4.8. Influence of acceleration on Digimax pedometer sensitivity at 3 stride settings. Median and 95% CI.

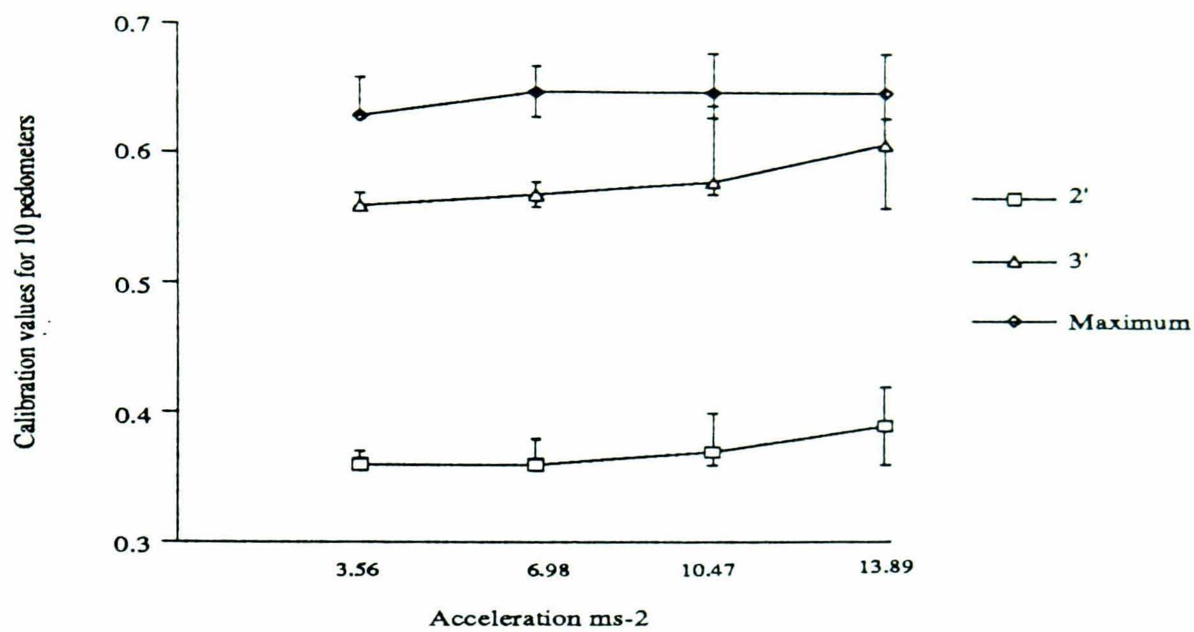
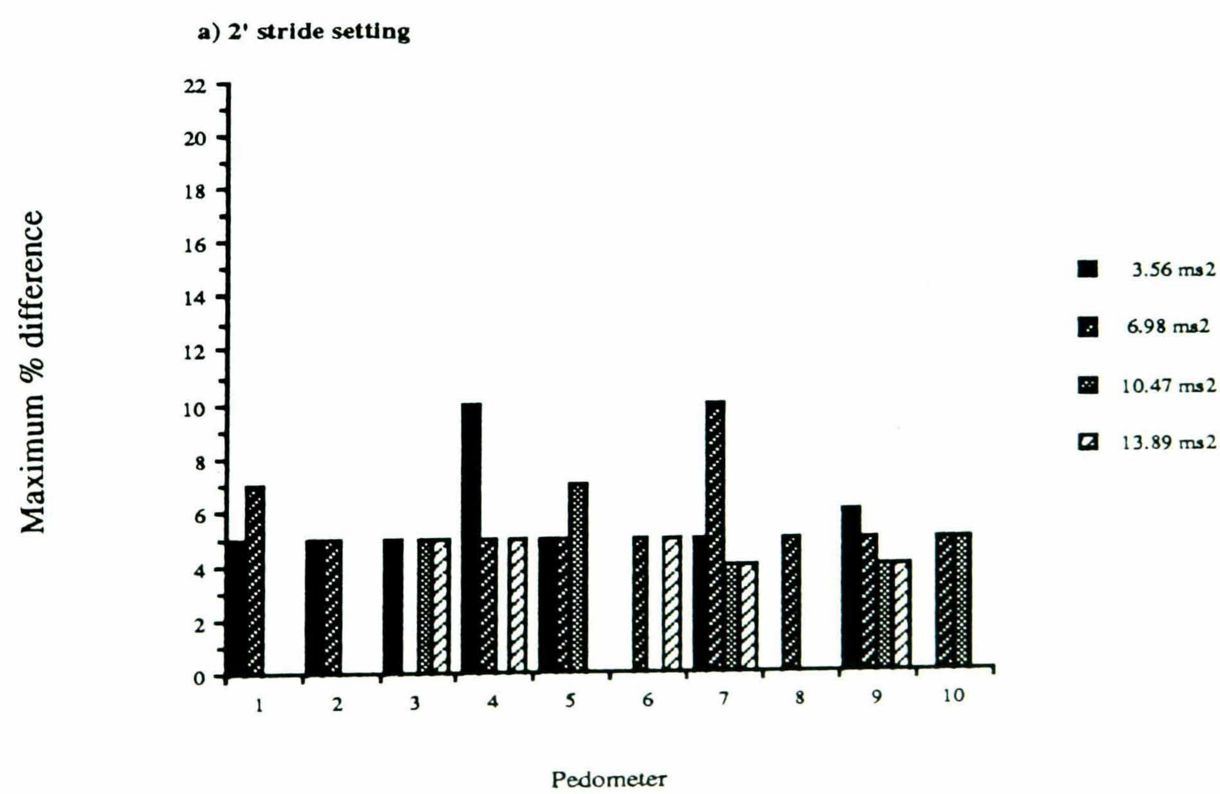
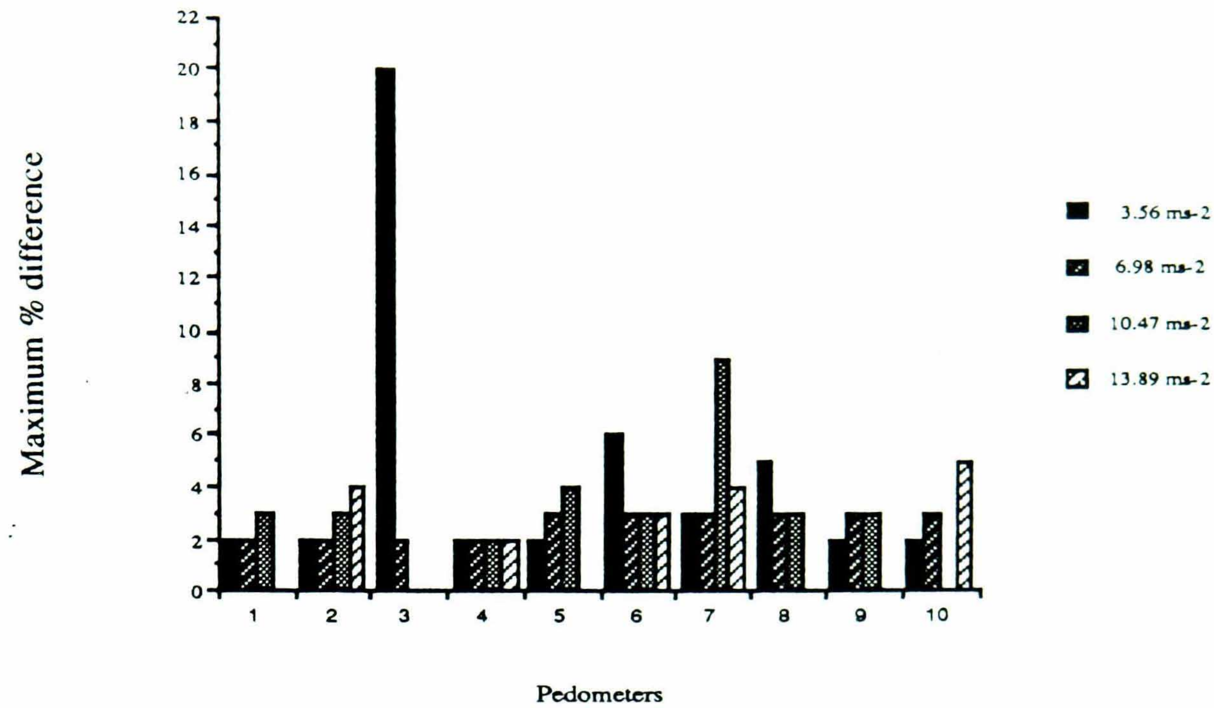


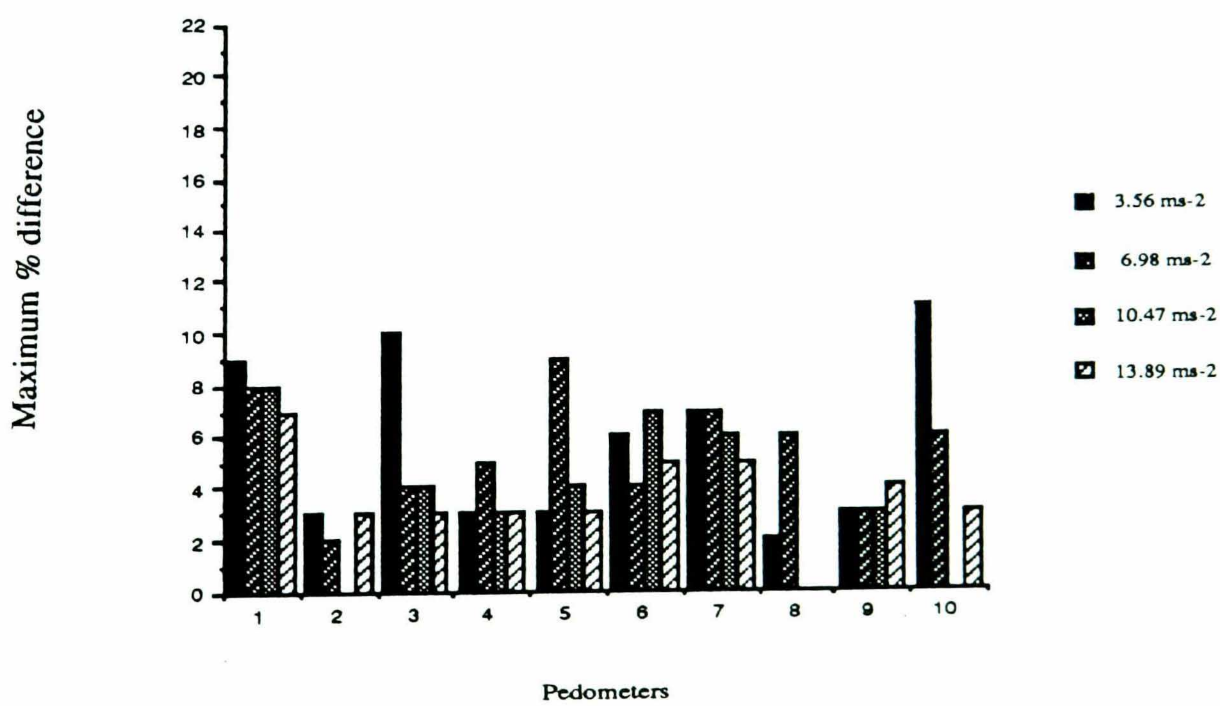
Figure 4.9. The variability in scores for 10 Digimax pedometers after 10 successive repetitions of 3000 steps.



b) 3' stride setting



c) Maximum stride setting



b) The validity and reliability of the belt-worn pedometer when used to assess distance walked.

A procedure similar to that used with the Pinion pedometers was adopted for this stage. The main difference was that only one pair of pedometers were worn by subjects when walking on the treadmill, as only the 'maximum' stride setting was investigated.

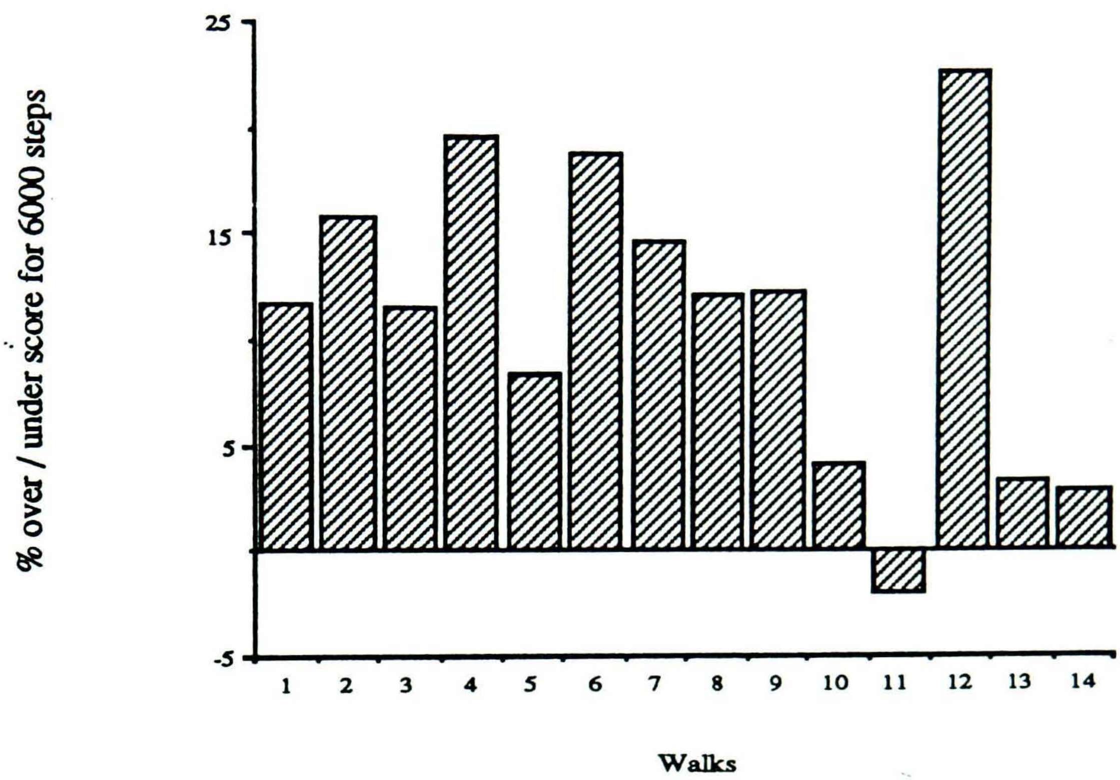
Results

Figures 4.10 shows the relationship between the converted scores and counted steps when a pair of pedometers were worn by one subject for 14 walks (the same subject who performed 10 walks in the previous test). The mean overscore was 11.1% (95% CI 7.3 to 14.9) over 6000 counted steps. On all the walks the scores from the pedometer worn on the right side was greater than that from left, and ranged from a difference of 2% to 48%.

The results for the 8 other subjects are shown in Figure 4.11. Each subject performed 2 walks and the mean value for the 16 walks was an overscore of 1% (-9.6 to 11.6). Coefficient of reliability for the pair of walks was 33.9%. The subjects generally demonstrated higher scoring from the right side. The magnitude of the difference between the two sides varied between and within subjects over the two walks. In one subject the scores from the right-side were 2% higher than the left on one walk and 63% higher on the repeated walk.

The mean overscore for the combined 30 walks was 5.5% (2.3 to 8.7).

Figure 4.10 a) Scores from Digiwalker pedometer at maximum stride setting on repeated walks by same subject.



b) Difference between right and left scores for same subject on repeated walks.

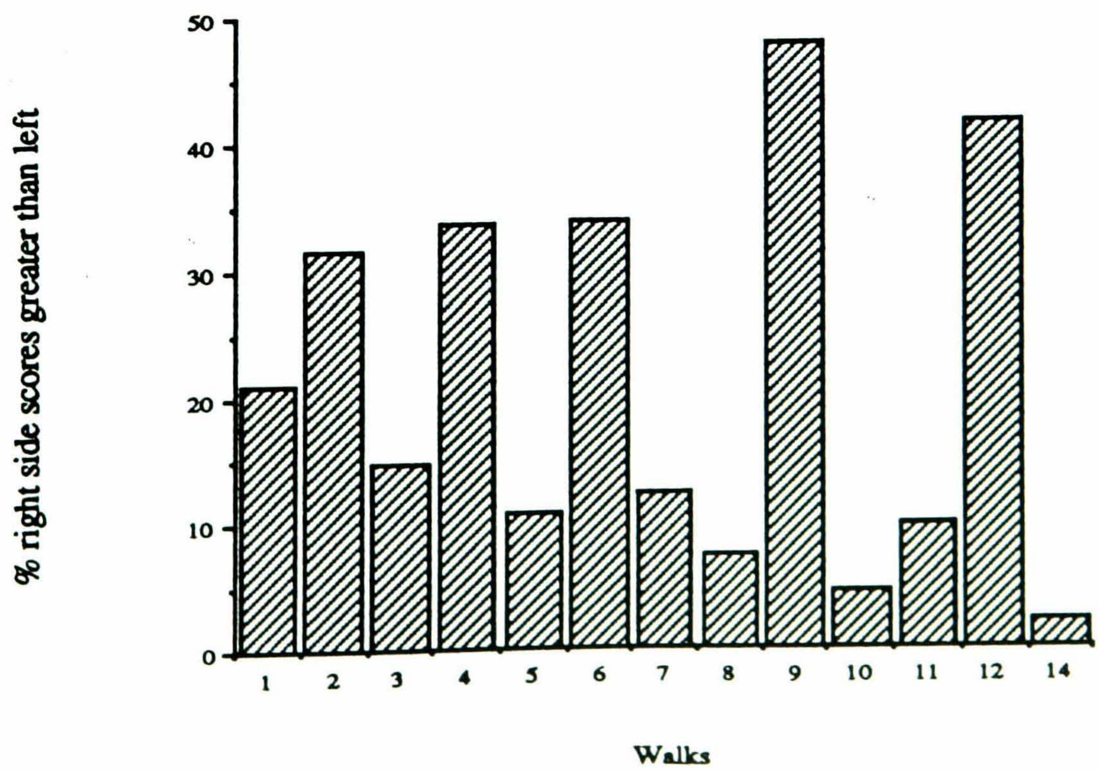
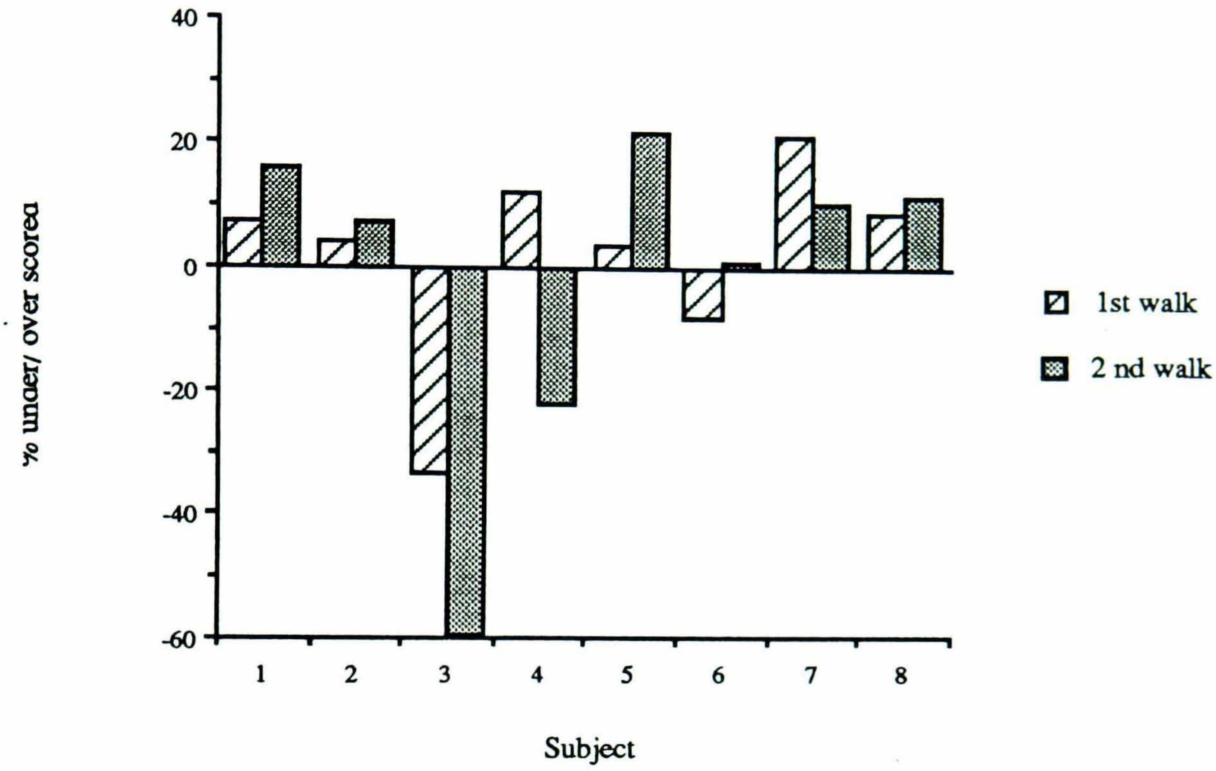
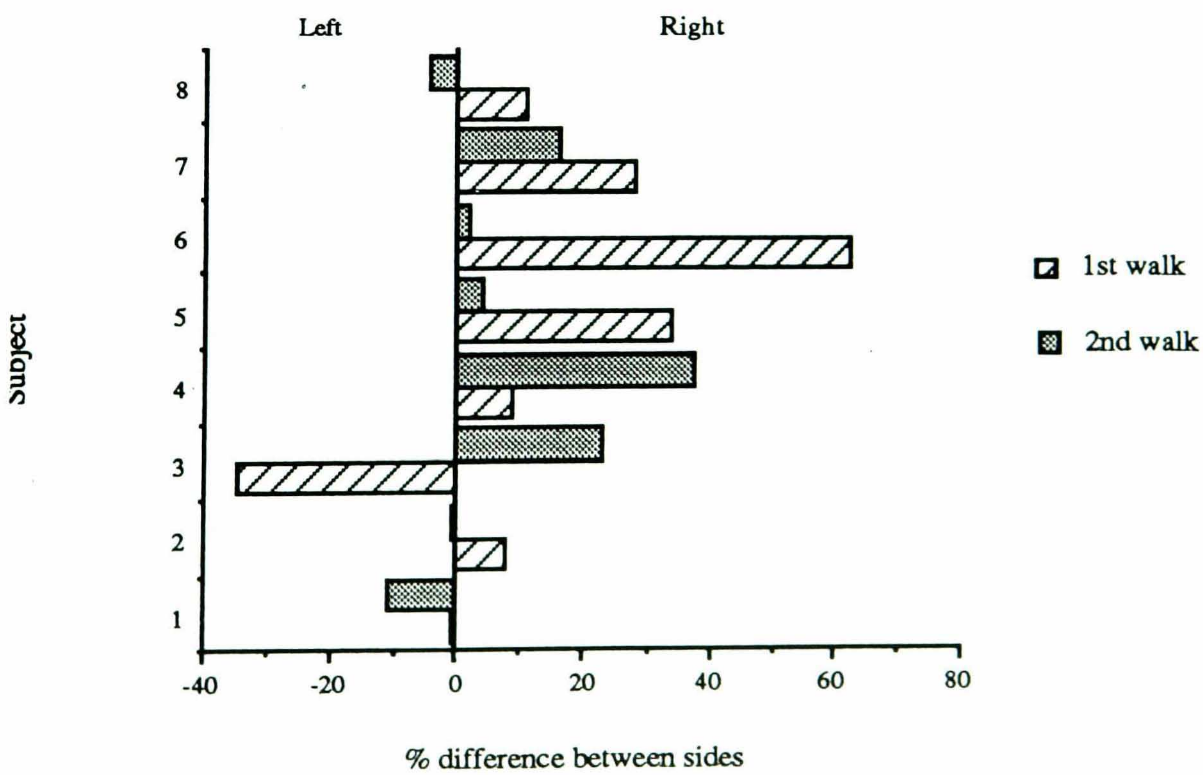


Figure 4.11 a) Comparison of Digimax pedometer scores at maximum stride setting for 8 subjects.



b) Difference between right and left scores with respect to the highest score for repeated treadmill walks.



Discussion

The selection of the 'maximum' stride setting as the most suitable for use as a measuring tool was based on the first part of the investigation. It was identified as the setting least affected by changes in acceleration and was stable over repeated 'step' cycles on the calibration rig.

The second part of the test showed that the maximum stride setting tended to overscore in comparison with a known number of steps, although less than with the Pinion pedometer.

This brand of pedometer was also prone to malfunction and it would appear this is a problem common to the 'pendulum and cog' design of pedometer.

The magnitude of the higher right side scores for the 14 walks by the same subject would suggest that this was not solely attributable to asymmetry of gait but probably also contained a degree of pedometer dysfunction. In order to identify an aberrant pedometer, the pedometers were worn on different sides on alternate walks. If the difference was due to a consistently malfunctioning pedometer, high scores on the left would also be expected over the walks.

The difference in scores between repeated walks may have been due to either changes in the style of gait, although precautions were taken concerning type of clothing and time of day, or indicate low reliability of the pedometer. Results from the changes in scores over ten repetitions suggest the latter may have been the main contributor, especially as the maximum stride length was minimally affected by changes in vertical acceleration as would occur with changes in gait.

CONCLUSION

Whilst the reliability and tendency to overscore does not make the Digimax pedometer a precise measuring instrument, it could be used to detect changes in ambulatory activity providing the magnitude of the changes are greater than the imprecision of the pedometer.

A limitation of using walking on a treadmill to determine the validity and reliability of a pedometer is that it only approximates to the environment in which the pedometers will normally be worn. Unfortunately there was not a 'gold standard' method of measuring footfall available with which to compare the pedometer scores during normal activity.

From the investigations into both of these pedometers some guidelines for practice were devised to maximise the accuracy of the results. These were:-

a) the calibration factor should be checked before and after use and the mean value used to convert the scores into footfalls

b) a pair of pedometers should be worn to detect pedometer dysfunction and asymmetry of gait.

c) If the difference between the scores from both sides was greater than 5% they should not be used, unless asymmetry of gait was suspected.

d) In order to distinguish between pedometer dysfunction and asymmetry of gait, the pedometers should be worn on the opposite side. If the difference is still the same, this suggests asymmetry is present and the results could still be of value.

4.2.3 PSYCHO-SOCIAL OUTCOME MEASURES USED IN STUDY.

As a result of the preliminary investigations the following outcome measures were used in the study:-

a) The Hospital Anxiety and Depression Scale (Zigmond and Snaith 1983) was used to measure changes in anxiety and depression. This questionnaire consists of 14 questions divided equally between the 2 areas (see appendix D). It is easy to understand, self-administrated and quick to complete and has been validated by the authors on a range of patients. Each aspect is scored separately, with scores ranging from 0 (no problems) to a maximum 28. Patients with scores of 11 or higher are considered to show clinical states of anxiety or depression.

b) A modified Edinburgh Rehabilitation Status Scale (ERSS) questionnaire was used to measure changes in functional activity and return to functional lifestyle (see appendix C). The range of the total score is 4 to 16, with a low score indicating good rehabilitation status.

c) Patients wore a pair of 'Digimax' pedometers on their waistband to record ambulatory activity. The scores from the pedometers were converted into footfalls by the method described earlier and the number of steps taken over seven days were used for analysis.

All patients completed the questionnaires at weekly intervals from entry to the end of week 6, and again on their follow-up visit. The pedometers were worn daily from discharge from hospital through to the end of the intervention period. They were also worn for a week prior to attending their follow-up visit.

4.3 MEASUREMENTS OF HAEMODYNAMIC PARAMETERS

4.3.1 SELECTION OF TEST TO DETERMINE EXERCISE CAPACITY

INTRODUCTION

The aim of the exercise test was to determine the physiological response of the body to predetermined work loads .

This information was required not only as an evaluative measure but also to form the basis for the prescription of the intensity of exercise training.

Various formal exercise tests are in current use and difficulties were encountered with the selection and timing of the most appropriate test. The test needed to allow the subject to attain their symptom-limited maximum at both 2 and 20 weeks post MI, and provide information relevant to changes in their cardiovascular capacity.

Moreover, whilst the intensity of the test needed to be sufficient to provide a stimulus to the cardiovascular system it also had to comply with recommended safety criteria for early testing.

The tests considered, in chronological order, were a) six minute walk test; b) two speed self-paced walk test and c) treadmill exercise tolerance test using a modified Bruce protocol. All of these tests have been used within the department with patients with chronic heart failure and MI (Cowley et al. 1991; Muller et al 1992; Walsh et al. 1995). The considered advantage of the walk tests were that they did not require any practice and by nature of their activity were less demanding than treadmill walking at the initial visits, and so less likely to potentiate cardiac problems.

Each of these tests were investigated for suitability on a patient population similar to that proposed for the main study. The patients were predominantly middle aged men who had experienced a first heart attack and the majority were taking a beta-blocking agent.

METHODS OF INVESTIGATION

a) Six minute walk test

Method

In this test the patient walked along a measured corridor for 6 minutes and the distance walked was noted. The patient wore a single channel cardiac telemetry unit so that the heart rate could be determined at intervals during the walk and to monitor for arrhythmia.

The patient was requested to walk as briskly as possible, so that on completion of the walk they felt they could not have walked any further. A print out of their ECG was obtained at minute intervals.

Because oxygen uptake was not measured during this test, training exercise intensity was based on the patient's heart rate equivalent to 40% peak oxygen uptake, typically 57% peak heart rate in healthy subjects (American College of Sports Medicine 1991).

Results

Ten patients undertook this test between the fifth and eighth day post MI. Nine of the patients were taking beta-blocking agents, and one patient failed to complete the time due to chest pain and fatigue.

The heart rate of the nine who completed the walk increased between 27% and 50% compared to resting levels (see Figure 4.15), and only two patients experienced any symptoms (leg fatigue). In all the patients their training heart rate was lower than their resting heart rate.

Utilising the method described by the American College of Sports Medicine (1991) the MET expenditure of the walk tests was estimated between 2.8 and 3.4 METs.

Conclusion

This test has the advantage that it is functional and requires little practice. However, it is unsuitable for use in determining a training heart rate based on the equivalent of 40% peak oxygen uptake.

The patients expressed difficulty in knowing how far they perceived that they could walk and often felt their lack of confidence limited their walking speed.

b) Two speed self - paced walk test

Method

This modified self-paced walk test involved patients walking 100 metres at their normal pace and then after a brief rest, repeating the distance at a fast pace. In this investigation the normal paced walk functioned as a means of allowing the patients to assess their exercise performance and increase their confidence.

Results

Ten patients performed this test between fifth and eighth day post MI and the results for the fast paced walk are shown in Figure 4.16.

In four patients their heart rate remained constant for both normal and fast walking paces, but walking time decreased. The heart rate of the

Figure 4.15 Increase in heart rate during 6 minute walk test

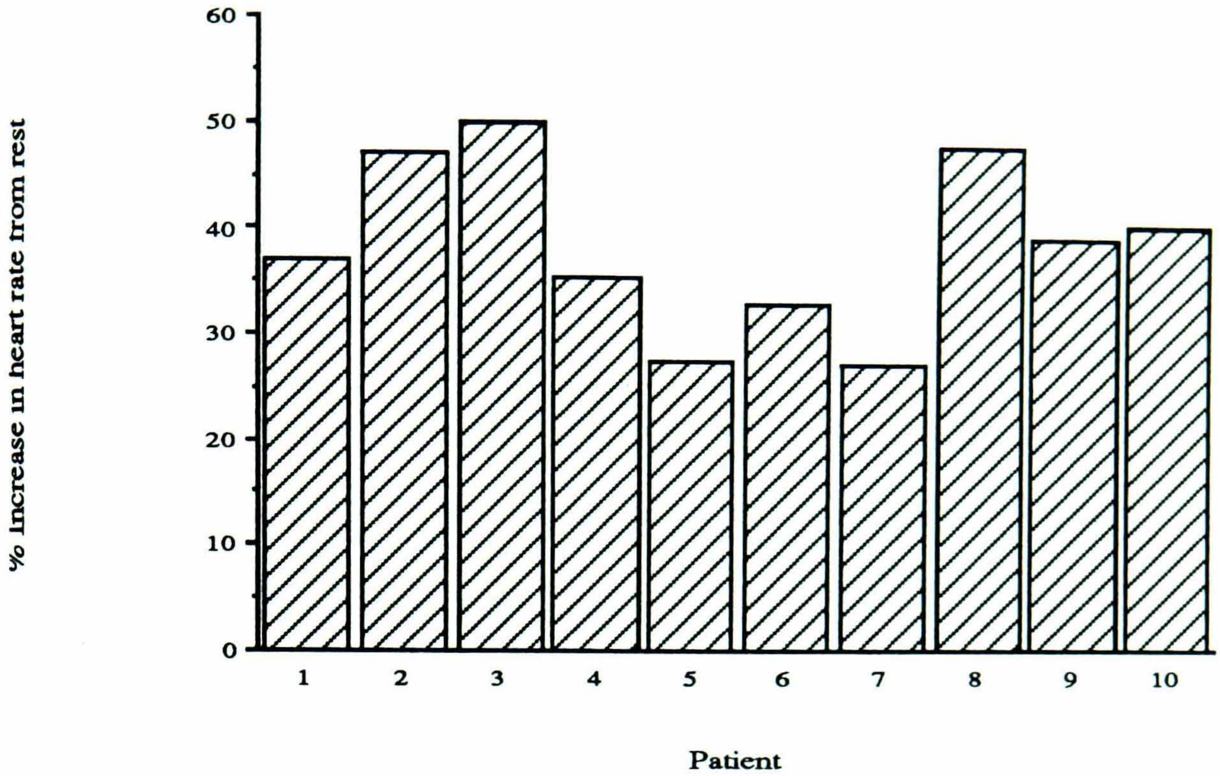
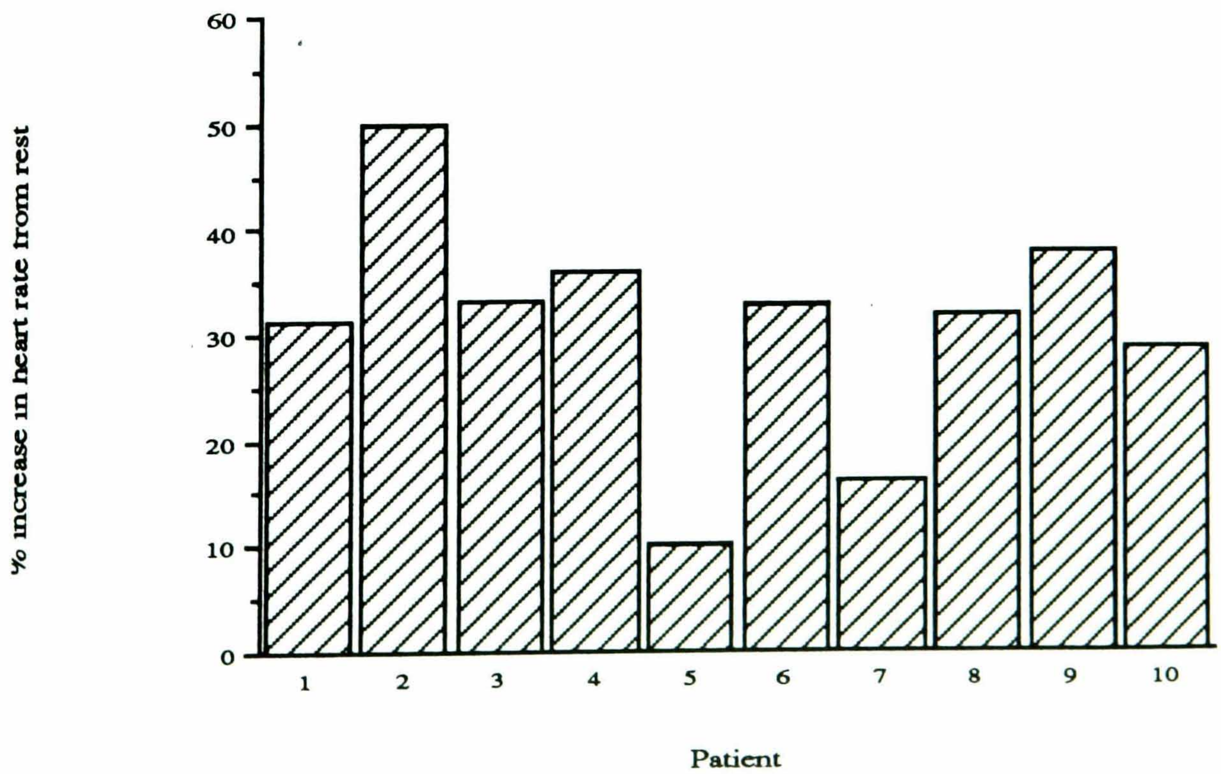


Figure 4.16 Increase in heart rate during fast pace walk test.



remaining patients who completed both walks increased with increased walking speed. The increases in heart rate were moderate, ranging from 31-50% of resting values. The training heart rate of 57% peak heart rate was lower than that of their resting level for all ten patients.

Patients were generally asymptomatic and reported only a slight increase in breathlessness during the fast paced walk. One patient felt unable to walk faster than at a normal pace but did not identify any specific symptoms, and another patient experienced some chest tightness during the fast pace walk.

The estimated range of peak METs achieved during the fast walk was from 2.7 to 4.4.

Discussion

Whilst in some patients the fast paced walk test provided an increased stimulus to the cardiovascular system, this was not apparent in the four patients whose heart rate remained unchanged. The latter may have experienced a high degree of psychological stimulus in the normal paced walk which elevated their heart rate. However, their resting rates were within expected ranges.

The low training rates rendered the fast-paced walk test unsuitable as a basis for the intensity of the exercise training programme.

In an attempt to obtain more data from both of these walk tests the use of an 'Oxylog' apparatus (Oxygen consumption meter - P K Morgan Ltd) was considered and explored.

The apparatus is placed in a harness carried on the back; a face mask with inspiratory and expiratory valves and a flow meter delivers the expired air, passing through a flexible hose to the instrument. The oxygen difference between the inspired and expired air is measured and the volume of oxygen extracted from the air is calculated and displayed as a cumulative total and minute values.

Difficulties were experienced in maintaining an airtight seal, and due to the continuous walking involved in the tests it was not possible to note the values for the minute uptake of oxygen during the walks. The only value that could be utilised was the cumulative total. In the 6 minute walk test this provided the value for the total walk, but the finishing time for the self-paced test usually fell between whole minutes and consequently the value would underestimate oxygen uptake.

Whilst these two tests have provided useful information for patients with heart failure and chronic obstructive pulmonary disease, (Foster and Thomas 1990; Foster et al. 1988; Guyatt et al. 1989) the increase in heart rate obtained with both forms of walk test was only moderate with early MI patients, and the exercise prescription equivalent to 40% peak oxygen uptake was less than the resting heart rate.

This method of evaluation was rejected on the grounds of failing to provide adequate stimulus to assess changes in cardiovascular physiology and an inappropriate basis for prescribing exercise intensity.

c) Treadmill exercise tolerance test

Introduction

An alternative method to walking for a preset distance or maximum speed is the exercise tolerance test. Whilst this test is extensively used with MI patients it is generally delayed until the third or fourth week on safety grounds.

In order to minimise the influence of learning on the results, a practice session would need to be performed prior to the collection of baseline data. This would provide an opportunity for the patient to familiarisethemselves with walking on a treadmill and using the equipment. Due to the small time window for enrolment, both the practice and baseline sessions had to be performed within 10 days post MI.

Consideration was given to the intensity and selection of end-points, taking into account the early timing of the test.

The literature identified a variety of end-points for exercise tolerance tests, particularly in the early stages of recovery. The main area of debate centred around the adoption of a symptom-limited or low level exercise test within the first few weeks post MI.

The low level test has been evaluated when used within days rather than weeks post MI (Burek et al. 1989; Topol et al. 1987). These tests often utilise an upper heart rate limit which may be based on a percentage of age predicted maximum heart rate or on some arbitrary heart rate. These criteria do not take into consideration the initial exercise capacity or heart rate of the patient and will be influenced by beta-blocking drugs.

Some investigators have compared the responses to both types of exercise test. DeBusk and Haskell (1980) used a heart rate end-point of 130 beats with patients 3 weeks post MI. They found higher indices of exercise capacity with the symptom-limited test and 45% of the patients reached the end-point for the low level test. Juneau et al. (1992) and Jain et al. (1993) performed similar studies with patients 7 and 6 days post MI respectively, and concluded that symptom-limited tests were safe with patients who had sustained an uncomplicated MI.

The choice of end-points other than that of symptoms is arbitrary and the use of a symptom-limited end-point is not without problems. It is subject to the perception of the patients symptoms by both the patient and investigator, the former being influenced by psychological as well as physiological factors.

Which end-point is selected will be influenced by the objectives of the exercise test, type of patient and medical management. A balance needs to be achieved between maintaining the safety of the test, extracting the relevant data and obtaining reliable and valid results.

Method

In order to fulfil the objectives of the study, a symptom limited exercise test was selected. When the practice test was performed within 7 days post MI a low-level protocol was performed, otherwise all the exercise tolerance tests were symptom-limited. A modified Bruce protocol was used for all the tests (see Table 4.5) and completion of stage II was chosen as the end-point for the low level test, estimated at 5 METs (17.5 VO_2 ml/kg/min).

Table 4.5 Protocol for modified Bruce exercise tolerance test.

Stage	**01**	**02**	**03**	**I**	**II**	**III**	**IV**	**V**
Speed (kph)	2.7	2.7	2.7	2.7	4.0	5.4	6.8	8.0
Slope ^{o}	0	1.3	2.6	4.3	5.4	6.7	7.2	8.1
Time (mins)	4	3	4	3	4	3	4	3

Topol et al. (1987) exercised similar patients at 3 days post MI up to levels equivalent to 8 METs without any adverse short term effects. However studies with animals have suggested high intensity exercise at an early stage predisposes the patient to stretching of the healing scar tissue. Consequently it was decided to adopt a cautious approach and place an upper limit on the intensity of the early exercise test which was principally intended as a practice walk.

A 12-lead ECG was used throughout the tests and continued for 5 minutes after the exercise had been completed. At the end of each stage blood pressure and Borg Rate of Perceived Exertion was taken. The latter facilitated communication between the patient and tester concerning the intensity of the exercise. The patients were instructed to walk until they experienced sensations similar to ones at which they would cease activity if they were walking alone.

Minute oxygen uptake was measured in seven patients by means of a mass spectrometer (VG Medicals Ltd, Cheshire).

Results

All of the 15 patients who performed this exercise test did so within 7 days of their MI and so were prohibited from walking beyond Stage II. There were no adverse reactions. The increase in peak heart rate ranged from 26 to 125%, (see Figure 4.17) and the maximum METs level in the patients who underwent gas analysis ranged from 2.6 to 8.3. The test was symptom-limited for 8 patients before reaching stage II, whilst 7 patients reached the end of stage II. In all 8 patients for whom the test was symptom-limited the training heart rate, based on 57% peak heart rate, was less than resting level.

Figure 4.17 Increase in peak heart rate during early treadmill exercise test.

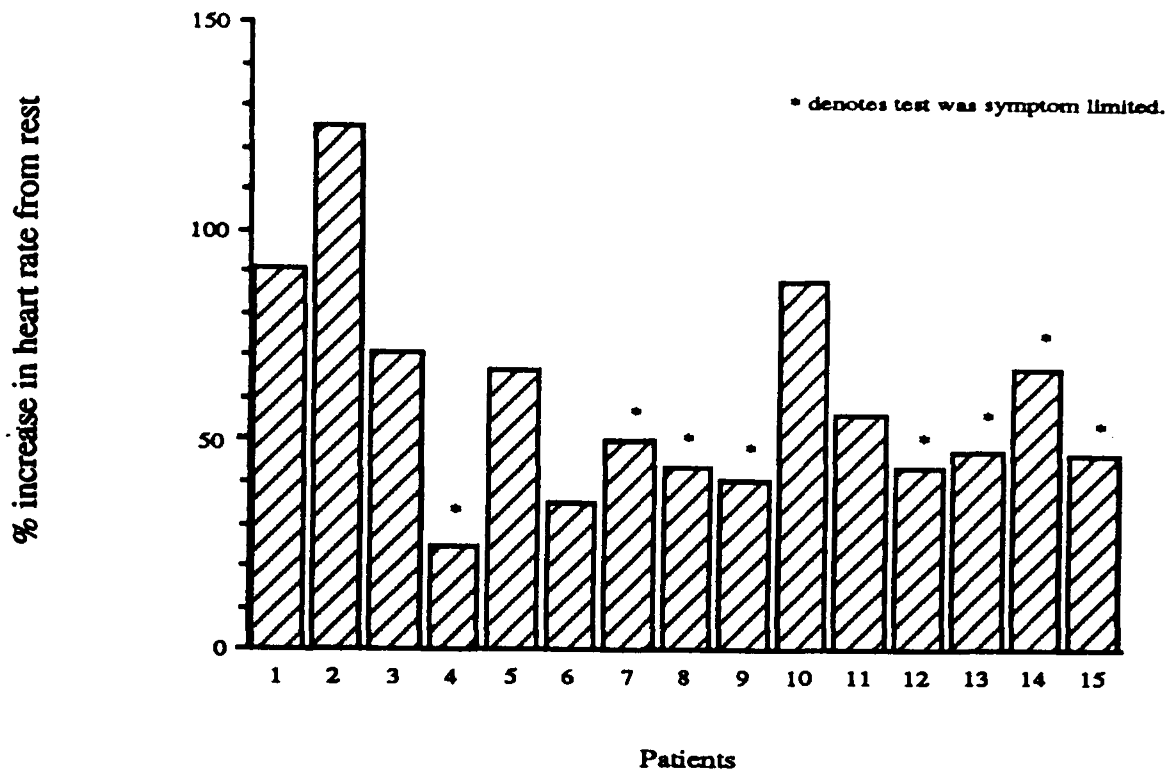


Table 4.6 Comparison of training heart rates determined by percentage of peak heart rate and oxygen uptake (all patients taking beta-blockers).
r_s = Spearman rank correlation coefficient.

Patient	Resting heart rate	57% peak heart rate	Heart rate at 40% peak oxygen uptake	r_s between heart rate and oxygen uptake.
1	56	61	90	0.32
2	47	60	65	0.43
3	85	81	97	1.0*
4	85	66	98	0.59
5+	58	49	64	1.0*
6+	50	45	56	0.8
7+	55	46	59	0.8

+ denotes test symptom-limited ; * $p = 0.001$

Data concerning oxygen uptake was available for 3 of the 8 patients and heart rates comparable to 40% peak VO_2 were determined from the data by linear regression. All three patients were taking beta-blockers and showed high correlation ratios between heart rate and oxygen uptake, although only one reached significance (see Table 4.6, patients 5-7). Previous studies have found correlations of r 0.8 to 0.87 between heart rate and oxygen uptake in beta-blocked patients (Hellerstein and Franklin 1984; Hossack et al. 1980). The target training heart rates using gas analysis data yielded higher values than 57% of peak heart rate and were greater than resting levels.

This aspect was further investigated by comparing the relationship between heart rate and oxygen uptake in the other 4 patients who underwent gas analysis and completed the test protocol. Similar differences were found when training heart rates were compared between the two methods, with determination from oxygen uptake providing higher heart rates than an equivalent percentage of maximum heart rate.

Discussion

The patients generally achieved larger increases in heart rate than those obtained with the walk tests. However, if the training heart rate was based on 57% peak heart rate as in the walk tests, the training heart rate was still less than the resting rate. But when it was determined by regression analysis as 40% peak oxygen uptake from the patients own respiratory data it was above resting levels. This shows that whilst the linear relationship between heart rate and minute oxygen uptake may be maintained in these patients, the slope of the regression line is reduced compared to healthy subjects.

No adverse events occurred during or after the exercise tolerance tests.

The results from the exercise tolerance test suggest that the training heart rate can be determined from the minute oxygen uptake and the test is safe. It also suggests that whilst the linear relationship between heart rate and oxygen uptake may be maintained in these patients the slope of the regression line is reduced compared to healthy patients.

CONCLUSION.

From this investigation the treadmill exercise tolerance test appeared to satisfy the criteria of an exercise test suitable for study purposes.

The patients derived confidence from exercising in a closely monitored environment, and the test appeared safe for use in patients with a recent MI. The analysis of respiratory gases provided information concerning physiological recovery and provided a basis for determining the target training heart rate for those in the exercise group. The test also appeared to provide scope for measuring an increase in the patients aerobic capacity.

4.3.2 MEASUREMENT OF CARDIAC OUTPUT

All subjects performed two exercise tolerance tests within 10 days of MI following the modified Bruce protocol (see Table 4.5). The first was performed around the time of discharge as a familiarisation session. The subjects who were to attend the rehabilitation programme underwent further exercise tests at fortnightly intervals during the 6 week programme and then 3 months after completing the programme, approximately 5 months post MI (week 18). To keep their contact with the hospital to a minimum, the control group only performed exercise tests at entry, week 6 and 18 (see Figure 4.1).

The tests were performed at the same time of day for each subject and in a temperature controlled environment of approximately 24^{o} C. Patients underwent an overnight fast for morning visits, or only had a light breakfast for afternoon visits. They rested for 30 minutes prior to measurements being recorded. A medical doctor, who was 'blind' to patient allocation, supervised the exercise test. As far as possible the same laboratory technician was present for all the measurements from the same subject, thus minimising measurement error.

Non-invasive measurements of cardiac output using the indirect Fick rebreathing technique were made at rest, stage 01, 03, II and IV to provide information on exercise-induced changes in central haemodynamics.

The Fick principle states that 'the total uptake or release of any substance by an organ is the product of blood flow to the organ and the arterio-venous concentration difference of the substance' (Ehlers et al. 1986). There are several investigative methods which utilise the Fick principle and these can be categorised as direct, invasive methods or indirect, non-invasive methods. These use oxygen, dilution of dye and change in temperature or carbon dioxide to assess cardiac output.

Indirect Fick principle

The indirect Fick principle using carbon dioxide as the indicator is well established in this laboratory (Cowley et al. 1986a; Muller et al. 1992; Walsh et al. 1995). This non-invasive method has the advantage that the partial pressure of carbon dioxide (PCO_2) in the pulmonary artery (i.e. mixed venous blood) can be easily measured by the equilibrium method of rebreathing and pulmonary venous (i.e. systemic arterial) PCO_2 can be derived from endtidal PCO_2. Carbon dioxide production is calculated from minute ventilation and mixed expired carbon dioxide concentration. These three variables are used to solve the Fick equation:

$$\text{Cardiac Output} = VCO_2/CvCO_2\text{-}CaCO_2 \text{ (L/min)}$$

where VCO_2 = minute CO_2 production

$CvCO_2$ = concentration of CO_2 in mixed venous blood

$CaCO_2$ = concentration of CO_2 in arterial blood

The validity of this method has been compared to that of thermodilution and the direct Fick technique, which is considered the 'gold standard'. Both methods are invasive, involving insertion of a right heart catheter and/or sampling of arterial blood. Studies have shown the rebreathing method both over and under-estimates cardiac output compared to the other two methods.

In a study involving 17 healthy subjects Muiesan et al. (1968) found the rebreathing method underestimated cardiac output compared to direct Fick measurements. Cowley et al. (1986a) did not find any mean difference between the two methods for 10 patients with cardiac disease and Reybrouck and Fagard (1990) found it tended to overestimate at rest (mean difference 0.5 L/m) in 16 subjects with hypertension, whilst the mean difference was minimal during exercise. The variation in results for the rebreathing method has been found to be higher at rest than during exercise (Fagard and Conway 1990).

Most importantly, despite the over and under-estimation of the rebreathing method, all the studies found high correlations between the different methods.

Due to the invasive nature of the direct Fick method the validity studies have by necessity been based on small numbers of subjects with varying underlying conditions. This limits their applicability, with only the patients used by Cowley et al (1986a) being similar to the study sample. The results of the latter suggested that measurement of cardiac output by the CO_2 rebreathing method compares satisfactorily with other techniques. It also has the additional advantage that it is non-invasive and easy to use during ambulatory exercise.

Procedure

The procedure involves the subject breathing through a mouthpiece and flow meter whilst wearing a nose clip. The mouthpiece is connected to a mixing box through which the subject inhales room air and the box collects expired gas. Endtidal CO_2 concentration is sampled from the mouthpiece by means of a tube that is connected to a gas analyser and mass spectrometer, and mixed expired CO_2 is measured from the mixing box.

For the first minute of the measurement the subject breathes normally whilst the expired gas is sampled continuously at the mouth and from the mixing box, providing a real time plot of PCO_2 measured at the mouth. During this time the mean endtidal value of PCO_2 is calculated from each breath and the minute volume and mixed expired PCO_2 are used to calculate CO_2 production. After this, the subject performs a normal exhalation and a tap between the mixing box and an anaesthetic bag, which contains 1-1.5 litres of approximately 10% CO_2 in oxygen, is opened. The subject then breathes rapidly for approximately 15 seconds until a plateau is reached on the display screen of the mass spectrometer. This indicates an equilibrium between alveolar PCO_2, as represented by PCO_2 measured at the mouth, and mixed venous PCO_2, and is considered an estimate for the latter.

An underlying assumption of this technique is that the composition of alveolar air is uniform throughout the lungs. This may not be the case where a mismatch of ventilation-perfusion is suspected. In this instance there may be a continued increase in the values obtained for mixed venous PCO_2, with prolonged rebreathing until a satisfactory plateau is obtained and an underestimation of cardiac output (Muiesan et al 1968).

Reproducibility of measurements of cardiac output.

Prior to this study the repeatability of the rebreathing technique used in this laboratory had been established for both groups of patients. Batin (1994) measured the cardiac output of 60 patients following a MI who were familiar with the equipment, and repeated the measurements 1 to 2 days later. The mean difference between the measurements and coefficient of repeatability for cardiac index were 0.26 L/min/m^2 and 2.1 L/min/m^2 respectively. This indicated that the measurements were reproducible and could be used to assess longitudinal changes.

To improve the reproducibility of assessments of exercise capacity many studies include a practice session prior to the data collection period to allow the patients to familiarise themselves with the measurement procedures. Most of the patients in the early rehabilitation study were not familiar with the exercise measurement techniques, but due to the narrow time window between the MI and entry into the study (maximum 10 days) the period for familiarisation with the equipment was limited to one practice session for the majority of patients.

To determine whether one practice session was sufficient to minimise the influence of learning effects, a preliminary investigation was performed to examine the difference in values between the first, second and third session on the treadmill. Data for a similar patient group obtained at a similar time post MI was available from a previous study performed within the same exercise laboratory (Batin 1994). The increase in cardiac output from rest to peak exercise level at all 3 visits was analysed. Table 4.7 shows that the difference between the mean values on the second and third visits was 3%.

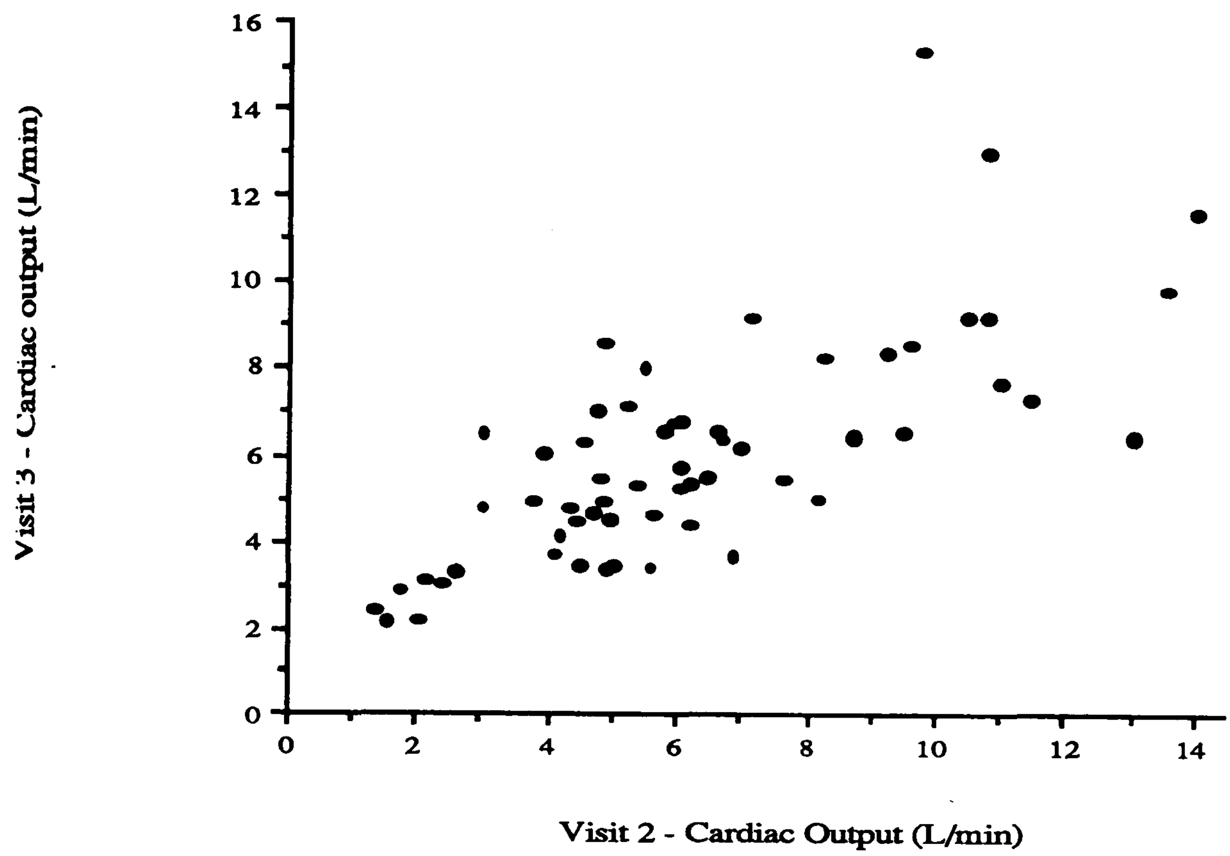
Table 4.7 Comparison of cardiac output measurements for first, second and third visit (n=60). Mean and 95% CI.

Visit	Increase in cardiac output (L/min) from rest to peak exercise level.	
	Mean	**95% CI**
1	6.3	5.5 to 7.1
2	6.2	5.5 to 6.9
3	6.0	5.4 to 6.6

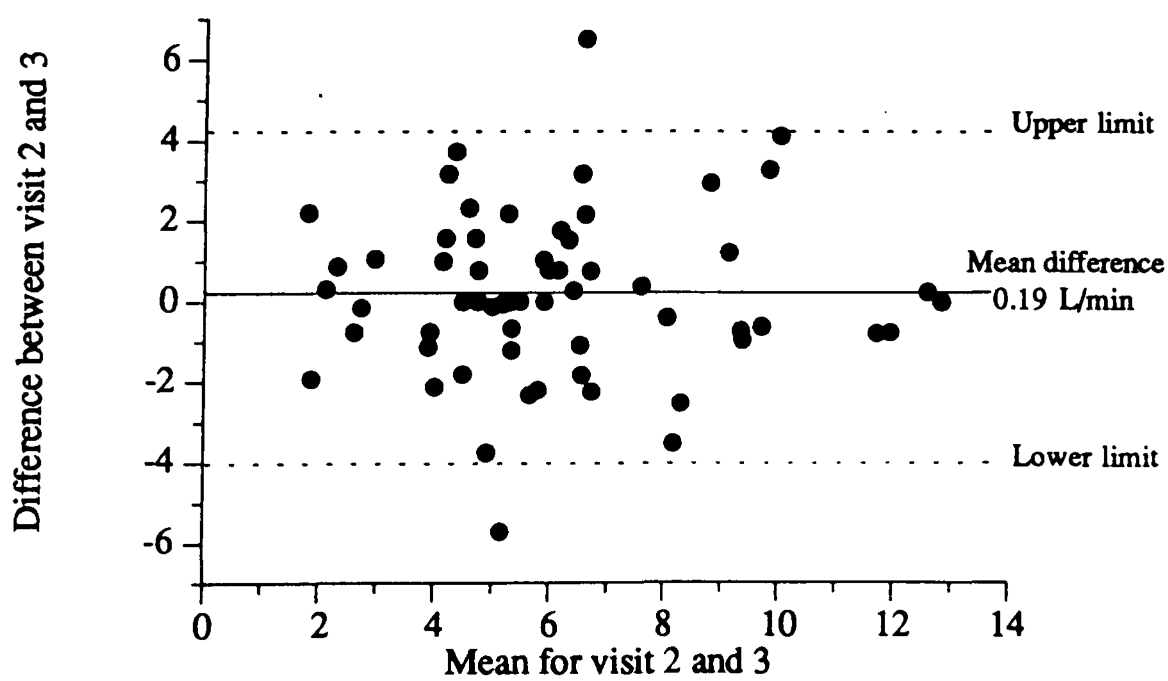
The difference for the values between the second and third visit was further examined to see the magnitude of any learning effects after the second trial. A scattergram showed a close linear relationship for the two visits whilst the limits of agreement method (Bland and Altman 1986) identified a mean difference of 0.19 L/min, with a coefficient of repeatability 0.87 L/min (see Figures 4.18).

From this data one practice trial was considered sufficient to avoid significant changes in values attributable to learning effects. Subjects who experienced obvious problems in using the equipment during their first 2 visits took no further part in the study.

Figure 4.18 **a)** Comparison of increase in peak cardiac output from rest on visits 2 and 3 for 60 patients. (Data from Batin 1994)



b) Limits of agreement for increase in peak cardiac output (L/min) on visit 2 and 3, using same data as above.



4.3.3 MEASUREMENT OF LIMB BLOOD FLOW

Measurements of limb blood flow in both studies were performed to investigate peripheral adaptation following exercise training and the distribution of blood flow on cessation of exercise. Simultaneous measurements of forearm and contra-lateral calf blood flow were made by venous occlusion plethysmography with mercury in silastic strain gauges.

Patients underwent measurements of resting and post-exercise limb blood flow on entry to the study, and at week 6 and 18. The blood flow was measured at rest and at minute intervals from the third to thirteenth minute after a fixed sub-maximal exercise test. The workload of the test was that which required an oxygen consumption of 12 mls/kg/minute (Cowley et al. 1986b).

Venous occlusion plethysmography

The method used was that described by Whitney (1953) and is now an established technique in this laboratory (Cowley et al 1986b; Muller et al. 1992; Walsh et al. 1995). It is based on the premise that arterial blood flow can be indirectly determined by occluding venous flow and the change in limb volume corresponds to arterial inflow.

The technique assumes that the changes in volume only occur transversely and not longitudinally, no blood escapes from the region and the arterial flow is not affected when the venous flow is occluded (Corbally and Brennan 1990; Formel and Doyle 1957; Sumner 1985). The changes in limb circumference are measured by mercury in silastic strain gauges; these form part of a Wheatstone bridge and alterations in the girth of the limb affect the resistivity of the column of mercury.

This technique has been compared with other methods of measuring limb blood flow i.e. Doppler ultrasonography; laser Doppler velocimetry; clearance techniques and nuclear magnetic resonance (Corbally and Brennan 1990; Jorfeldt 1988; LeJemtel et al. 1992). Whilst all methods have problems with reproducibility, venous occlusion plethysmography is the only non-invasive method suitable for serial, post-exercise measurements.

Disadvantages of the technique include that it cannot be used during exercise because muscle activity interferes with the recording procedure and it is unable to differentiate blood flow to the muscle from that to other structures within the limb. Clausen (1976) argues that post exercise hyperaemia is proportional to blood flow through exercising muscles at submaximal loads, so measurements taken within 3 minutes of terminating an exercise test were used to represent blood flow during exercise. Elia and Kurpad (1993) found that values for calf and forearm limb blood flow at rest using venous occlusion plethysmography were 1.5-2 times greater than muscle blood flow determined by isotope clearance at 25°C. This makes comparison of results between different studies difficult, but does not present problems in longitudinal studies provided the technique is reproducible.

<u>Reproducibility of the technique.</u>

The variability in venous occlusion plethysmography is considered to be influenced by physiologic change, variation in technique and systematic error in calculating blood flow from the chart traces (Altenkirch et al. 1990; Corbally and Brennan 1990; LeJemtel et al. 1992; Tonnesen 1968) Values of 15-25% generally have been found for the coefficient of variation, with higher values in the arm and at rest. The reliability of the model used in our laboratory had previously been determined for both groups of patients using the method described by Bland and Altman (1986). In patients with MI, measurements were repeated in ten subjects with a mean of 3.2 days between measures (Batin 1994). At rest there was a mean difference of 0.04 ml/100ml/min for the calf and 0.18 ml/100ml/min in the arm (coefficient of repeatability of 0.76 and 1.68 respectively). These changed post-exercise to mean values of 0.09 ml/100ml/min for the calf and 0.12 ml/100ml/min for the arm (coefficient of repeatability of 0.78 and 1.00 respectively). In the present study the same investigator was responsible for interpreting the chart images, thus eliminating inter-rater variation. In order to ascertain the intra-rater error in calculating blood flow from the traces, 54 pairs of complexes were subjected to a test-retest analysis (the mean of a pair of complexes represents one minute of blood flow). A mean difference of 0.14 ml/100ml/min was found between the two series of measurements, with a coefficient of repeatability of 0.17 ml/100ml/min. This was much less than the 20% inter-tester error found by Tonnesen (1968).

From these investigations the reproducibility was considered to be in accordance with that of other investigators.

Procedure

Measurements of limb blood flow were made with the subject supine, fasted and rested. The limbs being investigated were elevated above the level of the heart to allow free venous drainage out of the limb. The right arm was rested in a plaster cast with the arm abducted and elevated at the shoulder. The left leg was laterally rotated and slightly flexed at the hip, the knee flexed to approximately 50° and the ankle elevated so that the calf was above the level of the heart. This position avoided compression of the popliteal and femoral veins and was maintained by sponge supports. The limb supports were arranged so that the areas of the forearm and calf around which the gauges were to be placed were readily accessible and free from contact with any supporting structures.

Arterial occlusion cuffs were placed around the ankle and wrist and venous occlusion, or 'collecting' cuffs, around the thigh and upper arm. The mercury in silastic strain gauges were placed around the maximum circumference of the calf and forearm and detected changes in limb circumference. In order to avoid the effects of any change in ambient or skin temperature they contained a temperature compensation coil incorporated into their design. The arterial occlusion cuffs were maintained 50 mm Hg greater than systolic blood pressure and were kept inflated throughout the period of measurement. These excluded the complex vascular network of the foot and hand. The venous occlusion cuffs inflated and deflated cyclically at 15 second intervals to pressures 20 mm Hg below the arterial diastolic pressure. By intermittently arresting the venous return without interfering with arterial inflow, blood accumulated within the limb and caused an increase in limb volume. This stretched the strain gauges and altered their resistance, which was displayed as a deflection on chart paper. The rate of increase in volume corresponded to the rate of arterial inflow and the latter was determined from the chart images.

Preparation of strain gauges.

Before each set of measurements were made, appropriate sized strain gauges were selected, balanced and calibrated.

The balancing procedure was performed each time to ensure that the gauge was placed around the limb under the same magnitude of tension. The initial step of the procedure was to determine the baseline position of the chart recording pen for each gauge when the latter was excluded from the circuit (zero voltage). A 10g weight was suspended on the loop of the gauge, stretching it by 10% and altering its electrical resistance. This caused the chart pen to be deflected and it was returned to its original zero voltage position by altering the voltage on the potentiometers. When the gauges were applied to the limb the tension in the gauge was adjusted so that the recording pen was in this zero voltage position.

A 10g weight was chosen because the tension it created corresponded with the amount of tension required to hold the gauge in position against the limb without deforming the underlying tissues and produce a linear response for changes in limb circumference within the physiological range.

In order to convert the deflection recorded on the chart paper to changes in limb circumference, it was necessary to calibrate each strain gauge. This was performed after the limb blood flow had been measured and the settings were the same as those used with the subject. The strain gauge was placed on a calibrating rod which consisted of a clear perspex frame with a moveable end around which the strain gauge was looped. The position of the latter was adjusted until the voltage of the gauge was at its balance point (zero). With the chart paper running, the length of the gauge was then sequentially altered by a known amount (0.5 mm). From the deflections on the chart paper it was possible to determine the change in electrical resistance per 0.5 mm stretch of the gauge i.e. its calibration factor.

The speed of the recording paper and the circumference of the limb were required to determine the slope of the trace (corresponding to arterial inflow) from which limb blood flow (ml/100ml/minute) was calculated, using the relationship limb blood flow = slope/ calibration factor.

4.4 MEASUREMENT OF RESPIRATORY PARAMETERS

As well as providing measurements of cardiac output the arrangement of the breathing circuit, flow meter and mass spectrometer described in section 4.4.2 also provided information on oxygen consumption, carbon dioxide production and minute ventilation (VE) at rest and during exercise.

The mass spectrometer sampled expired air for 50 seconds during rest and for 25 seconds of each minute during exercise. This enabled the computer software to provide values for CO_2 production, O_2 consumption and VE (BTPS) for each minute during the exercise period. This information was not available for the last two minutes of the stages of the treadmill protocol when cardiac output was being measured. CO_2 production was calculated from VE and mixed expired PCO_2. Oxygen consumption was calculated from the product of VE and the difference between mixed expired oxygen concentration and atmospheric oxygen.

Values of O_2 consumption and CO_2 production were corrected for body weight (ml/kg/min) and the former was used to derive metabolic equivalents of the exercise (METs).

In addition to analysing the measuements independently, the relationship between VE and VCO_2 production were investigated as an index to alterations in ventilatory efficiency.

Reproducibility of measurements of oxygen consumption.

Prior to the study the effect of repeated treadmill sessions on the reproducibility of the results were examined. This was performed in the manner described for cardiac output (see section 4.3.2), with 60 post MI patients performing three treadmill tests separated by 1 to 2 days. Table

4.8 shows the difference between the mean values on the second and third visit was 3.5%.

Table 4.8 Comparison of measurements of O_2 consumption for first, second and third visit (n=60). Mean and 95% CI.

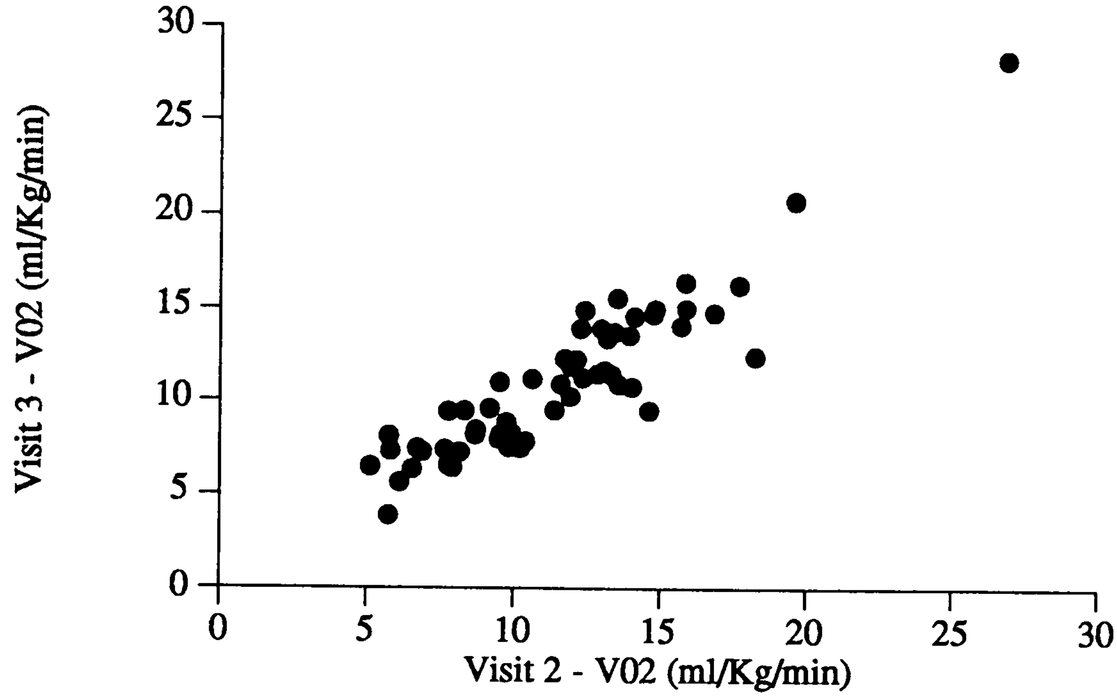
Visit	Increase in VO_2 (ml/kg/min) from rest to peak exercise	
	Mean	**95% CI**
1	10.2	9.1 to 11.3
2	11.6	10.5 to 12.6
3	11.1	10.1 to 12.2

The difference for the values between the second and third visit was further examined to determine the magnitude of any learning effects after the second trial. A scattergram showed a close linear relationship for the two visits whilst the limits of agreement method identified a mean difference of 0.41 ml/kg/min with a coefficient of repeatability 3.41ml/kg/min (see Figures 4.19). From this data one practice trial was considered sufficient to avoid significant changes in values attributable to learning effects. Subjects who experienced obvious problems in using the equipment during their first two visits took no further part in the study.

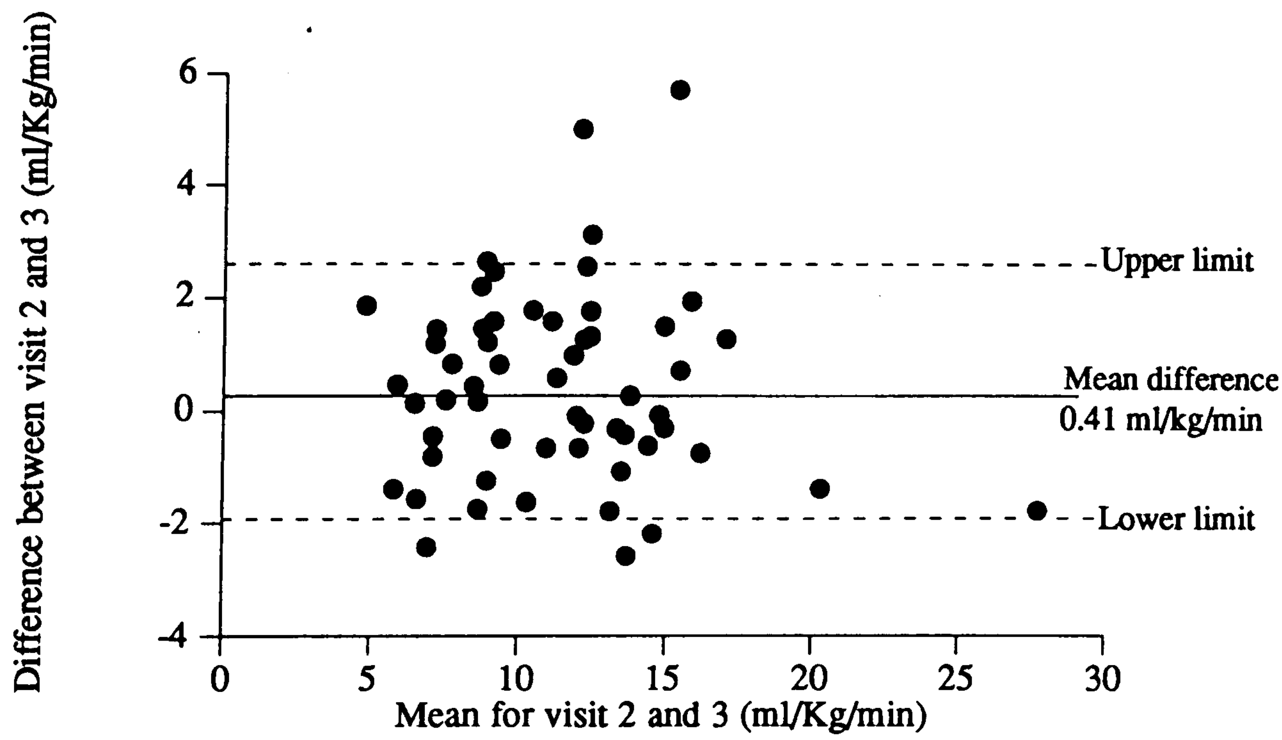
4.5 STATISTICAL ANALYSIS.

The change in measurements for each patient between entry and week 6, and entry and week 18 were determined and expressed as percentage change from entry.

Figure 4.19 a) Comparison of increase in VO_2 ml/kg/min from rest to peak value on visits 2 and 3. (Data from Batin 1994)



b) Limits of agreement for increase in VO_2 (ml/kg/min) from rest to peak value on visit 2 and 3, using same data as above.



Summary values are expressed as either median or mean with 95% Confidence Interval (95% CI). The latter were determined using the method described by Gardner and Altman (1989)

The scale and distribution of the data generally dictated that non-parametric tests were used in the analysis. Comparisons between each week of the psycho-social data were not made due to the dependent nature of the data for which there is not an appropriate non-parametric test.

The pattern of changes in parameters for the education and exercise groups were compared by a Mann-Whitney test using the area under the curve for measures at entry, week 2, 4 and 6 for each subject.

Kruskal Wallis one-way analysis of variance was used to detect any significant differences in the changes between the three groups at week 6 and 18. Where a difference was found, a Mann-Whitney test with a Bonferroni correction was applied post-priori to identify which groups were different. A one-way analysis of variance was used when appropriate.

Spearman rank correlation coefficients were used to determine the relationship between changes in different measurements.

Significance was determined at $p<0.05$.

The median change and 95% CI for each group was also determined, together with the differences between group medians using the method described by Gardner and Altman (1989). The latter indicates the difference between two groups for the changes being investigated. Briefly, it involves subtracting individual patient values in one group from another group, i.e. exercise minus education, (shown in the results tables as Exercise - Education) and determining the median and 95% CI for the difference from all the differences between the two groups. A negative value indicates the changes in the first group are less than those in the second group.

CHAPTER 5

RESULTS

5.1 CHANGES IN PSYCHO-SOCIAL MEASURES.

5.1.1 RESULTS

At entry, the levels for all the measurements were similar in each group and no significant differences were found between the groups.

The Hospital Anxiety and Depression scale classifies patients with a clinical anxiety or depressive state as those with scores greater than 11. All of the patients scores were below that level at entry, with patients in all groups generally demonstrating higher levels of anxiety than depression.

The weekly values for anxiety, depression, ERSS and pedometer scores are presented in Figures 5.1-5.4.

When the changes in scores were expressed as a percentage increase or decrease compared to entry, differences were found between the exercise and other two groups for increased pedometer scores at week 6, and decreased anxiety and improved rehabilitation status at week 18. There were no differences between any of the groups for changes in depression or between the education and control group for any of the measures. The changes and differences between the three groups are shown in Table 5.1 and 5.2.

Where large differences between groups failed to reach significance it was usually due to the overlap of the 95% Confidence Intervals. This can be seen at week 6 for the large decrease in depression in the two active groups compared to the control group, and the decreased anxiety and improved ERSS scores in the exercise group compared to the other

Figure 5.1 Weekly anxiety scores. Median with 95% CI.
A decrease in score indicates a reduction in anxiety.

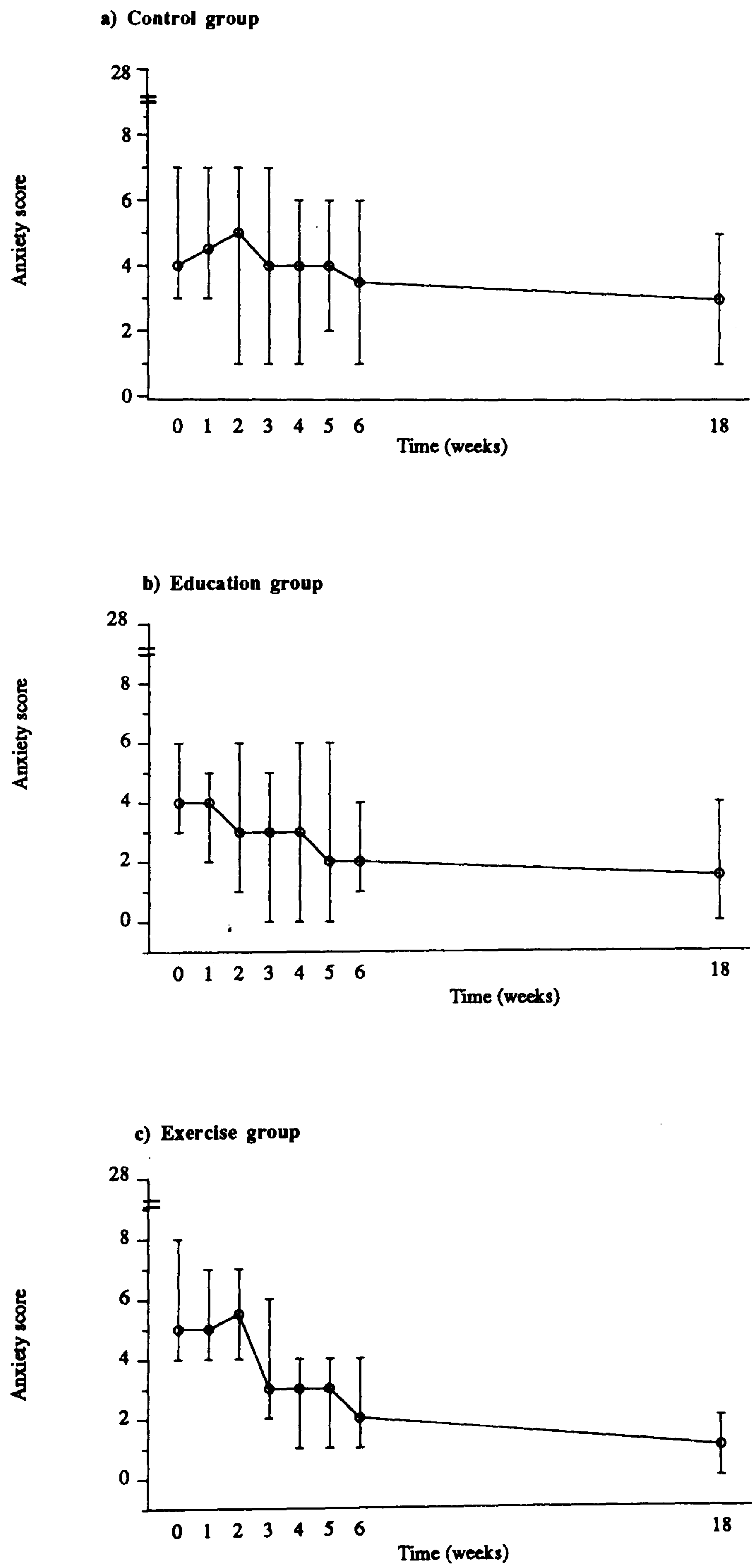


Figure 5.2 Weekly depression scores. Median and 95% CI.
A decrease in score indicates a reduction in depression.

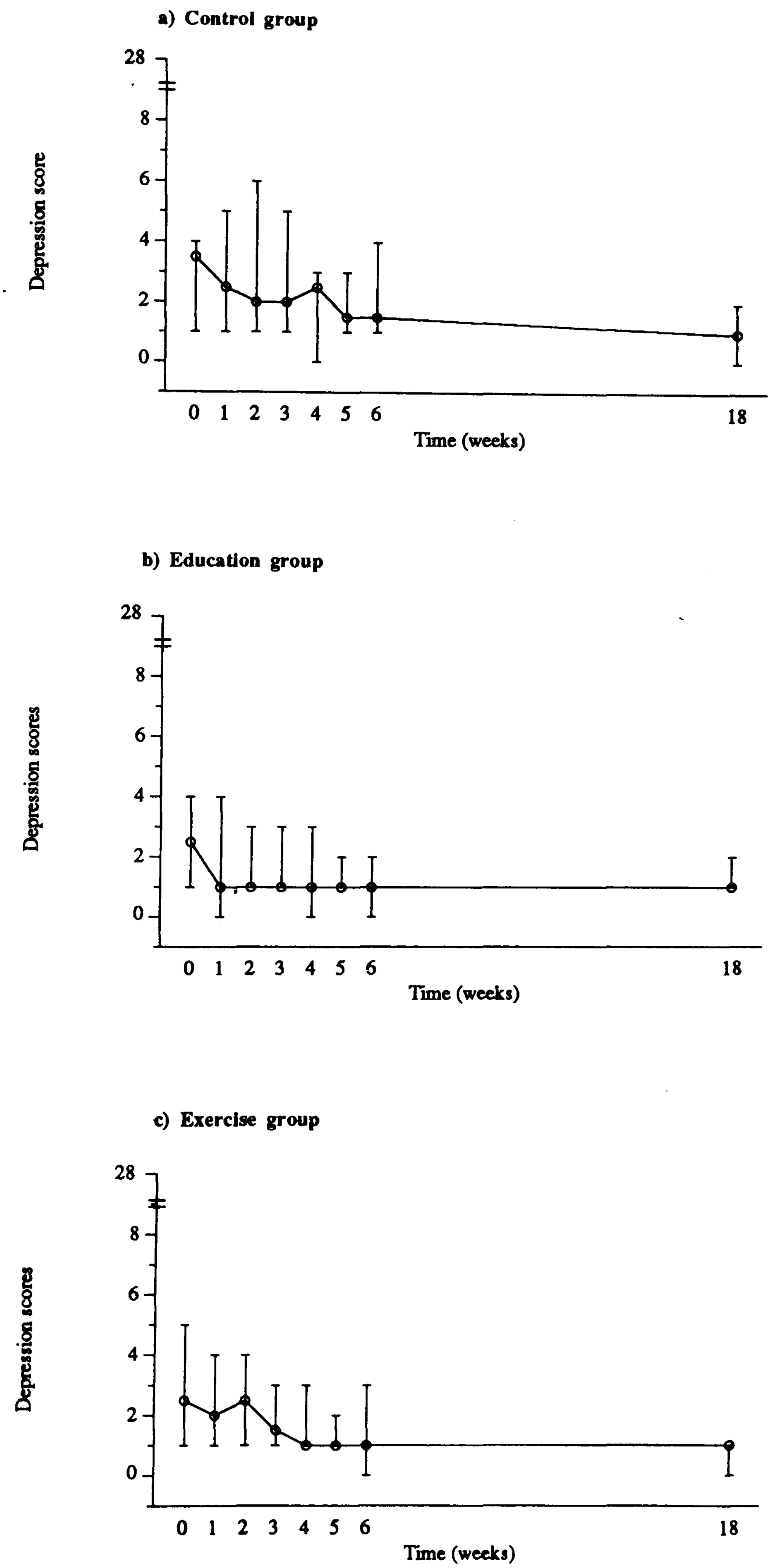


Figure 5.3 Weekly scores for ERSS. Median and 95% CI.
A decrease in score indicates improved status.

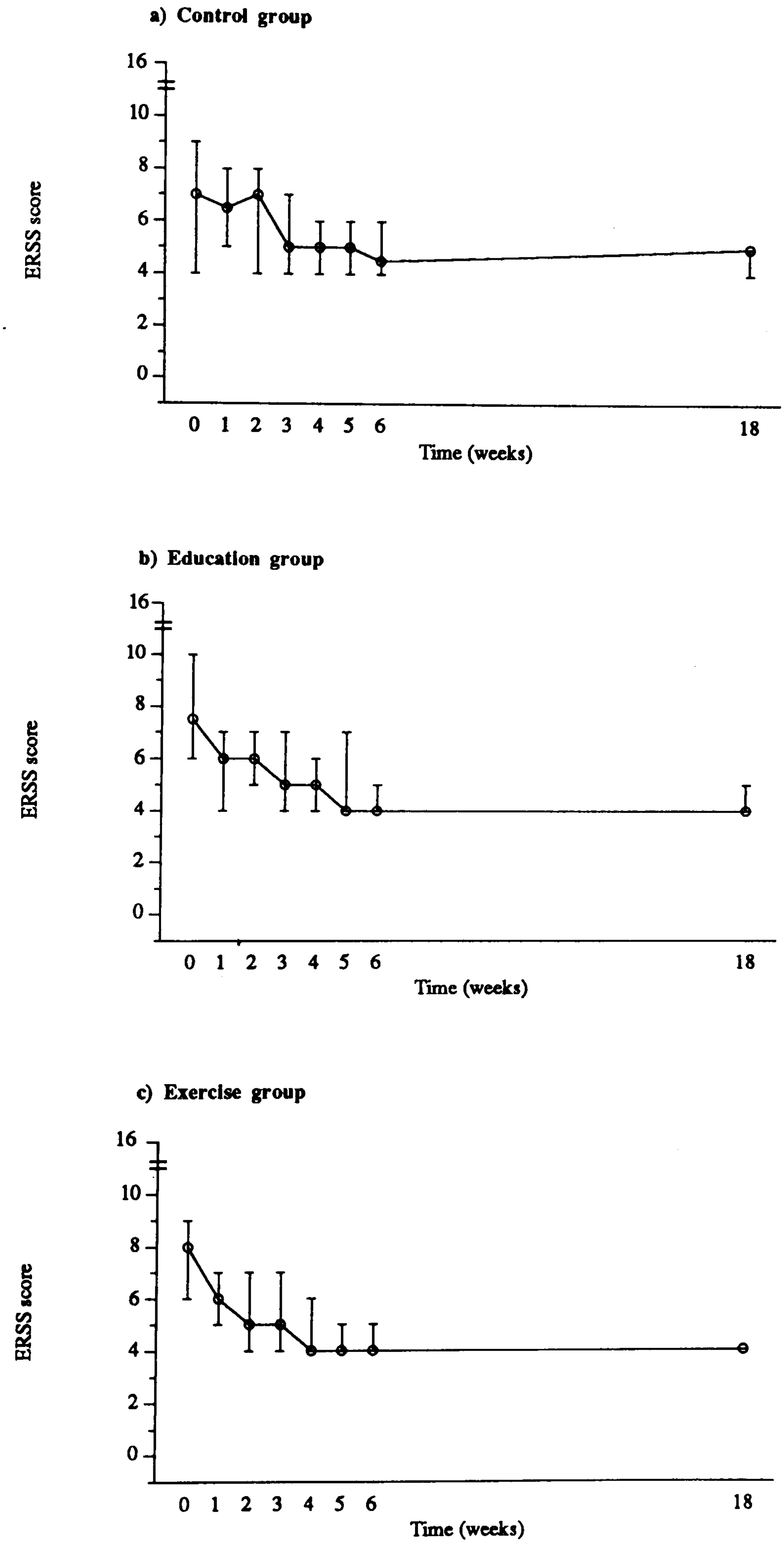


Figure 5.4 Weekly pedometer scores. Median and 95% CI.

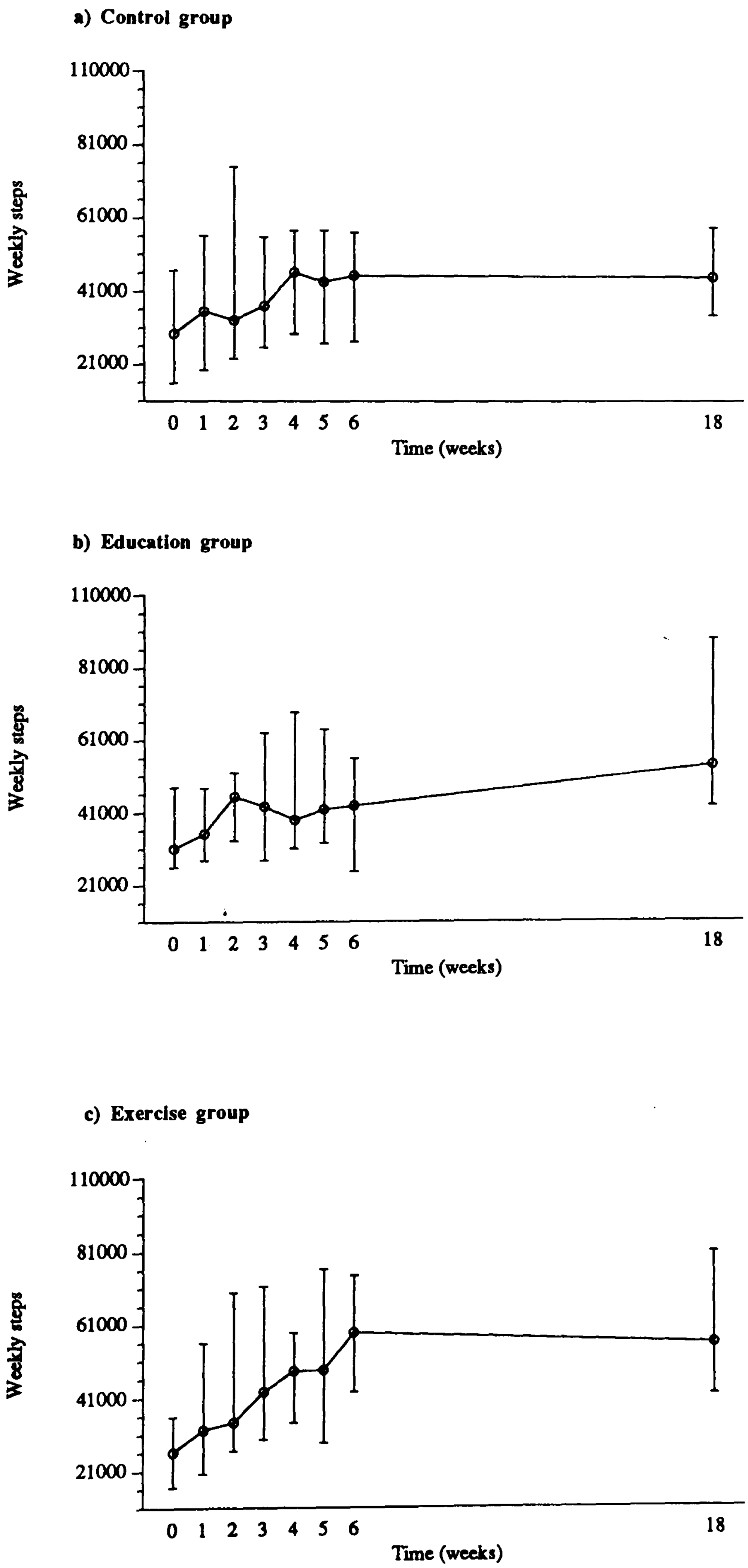


Table 5.1 Changes in psycho-social measures expressed as a percentage change from entry. Median and 95% CI.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Decrease in anxiety				
Control	22%	0 to 66	38%	0 to 66
Education	28%	0 to 75	50%	0 to 80
Exercise	55%	25 to 75	75%	50 to 88
Decrease in depression				
Control	0%	0 to 50	50%	0 to 75
Education	42%	0 to 71	40%	0 to 75
Exercise	50%	0 to 66	66%	0 to 80
Improvement in ERSS scores				
Control	21%	0 to 43	33%	0 to 50
Education	30%	0 to 44	32%	0 to 46
Exercise	44%	25 to 54	50%	33 to 60
Increase in pedometer scores				
Control	34%	21 to 110	72%	20 to 170
Education	53%	-12 to 81	76%	-16 to 186
Exercise	152%	67 to 207	115%	45 to 486

A minus sign indicates a decrease in score compared to entry.

Table 5.2 Differences between the group medians for percentage change in psycho-social measures. Median and 95% CI.

	Entry to Week 6		Entry to Week 18	
	Difference	95% CI	Difference	95% CI
Anxiety				
Exercise - Education	15%	-5 to 50	18% *	0 to 50
Exercise - Control	25%	0 to 55	23% *	9 to 50
Education - Control	0%	-42 to 23	5%	-25 to 25
Depression				
Exercise - Education	1%	-21 to 50	20%	-21 to 50
Exercise - Control	21%	-10 to 50	17%	-10 to 50
Education - Control	10%	-25 to 33	-8%	-35 to 25
ERSS				
Exercise - Education	12%	-6 to 25	17% *	1 to 33
Exercise - Control	20%	2 to 44	17% *	0 to 40
Education - Control	5%	-29 to 8	0%	-23 to 15
Pedometers				
Exercise - Education	100% *	43 to 160	39%	-42 to 118
Exercise - Control	77% *	10 to 134	44%	-9 to 107
Education - Control	5%	-33 to 46	1.5%	-76 to 59

* denotes p<0.05

A negative value denotes the changes in the first group were less than those in the second group.

groups. At week 18, a large difference was seen between the exercise and other groups for increased pedometer scores.

The relationship between the changes in different measurements within each group was investigated. In the control group there was a significant correlation between decreased anxiety and depression (r_s 0.48) at week 6, and between increased pedometer scores and decreased anxiety at week 18 (r_s -0.64). The education group showed a correlation between decreased anxiety and depression at both week 6 (r_s 0.6) and 18 (r_s 0.68). No correlations were found between any of the measurements for the exercise group.

No differences were found in the pattern of change between the three groups for any of the measures over the 6 or 18 week period.

5.1.2 DISCUSSION

All groups showed an improvement in all areas during the 18 week study period, with most of the improvement occurring between entry and week 6. This indicated that factors other than the rehabilitation programme were influencing the early recovery of the patients. These may have been spontaneous recovery or advice and information received from sources other than the rehabilitation programme i.e. in-patient information, medical contact and acquaintances.

The group who underwent the education and individual exercise programme showed significantly greater improvements compared to the other two groups for changes in pedometer scores, functional activity and decreased anxiety.

Changes in anxiety and depression levels.

Depression did not appear to be a problem in these patients, with low entry scores in all groups. The patients that attended the rehabilitation programme showed a greater reduction in scores during the intervention period than the control group.

Although Figure 5.2 suggests the rate at which the two active groups reached their lowest score was quicker than that of the control group, the median scores were accompanied by wide confidence intervals and the rates of change were not different.

The exercise group showed a large decrease in anxiety which followed an irregular pattern, with the greatest fall between week 2 and 3. This may have been attributable to early gains in confidence from performing supervised exercise without experiencing any adverse effects. The small difference between the control and education group at week 6 suggests that attending the education programme did not appear to lower anxiety levels. Similarly, the performance of regular exercise tolerance tests by the education group, in contrast to the control group, did not seem to reduce anxiety.

The correlation between the changes in anxiety and depression in the control and education groups indicated a general change in psychological attitude, although no significant changes in depression were detected. This improved outlook may explain the inverse correlation between pedometer scores and anxiety in the control group, whereby the change in their psychological state enhanced their activity level. The converse may also be true.

Changes in Activity.

In contrast to the early differences in pedometer scores, a significant improvement in ERSS values in the exercise group did not occur until week 18. However, the exercise group showed the greatest improvement for both measures at all time points, with the education and control groups showing similar changes in scores.

As the ERSS reflects the patients subjective view of how their function is affected by their MI, a relationship may have been anticipated between changes in pedometer and ERSS scores. The control and education groups showed an attainment of a steady state for both pedometer and ERSS scores between weeks 4 and 6, but the correlation between the changes in these two outcome measures for all the groups at weeks 6 and 18 was weak (ranging from r_s -0.24 to -0.26). This lack of correlation may reflect the difference between objective and subjective measures of similar parameters. Additionally, the scores from the pedometers only reflected changes in walking activity whereas the questionnaire was concerned with wider aspects of the patients life.

The questionnaire may have been influenced by some patients demonstrating an early ' ceiling effect' with the questionnaire, when they considered they had resumed previous functional levels within the first few weeks of entering the study. This limited the capacity of the questionnaire to detect any changes within the subsequent weeks. This may have been a problem inherent within the design of the questionnaire, or it may have been due to the perception of the patient or as a result of using patients recovering from an uncomplicated MI who quickly resumed their former activities without any problems.

The pedometer scores for the education and exercise groups were not systematically influenced by the performance of an exercise tolerance test at weeks 2 and 4, thus the absence of these tests in the control group should not have affected the result. The increase in pedometer scores for the education group and decrease for the exercise group during the 12 week follow-up period may have been a reflection of the activity levels required by their job. By week 18 (20 weeks post infarction) 11 patients in the exercise group, 9 in the education group and 8 in the control group had returned to their previous employment. Due to the depressed employment climate at the time this study was undertaken, aspects concerned with returning to work were not assessed. The fall in pedometer scores for the exercise group compared to week 6 may also have been due to the cessation of the supervised exercise programme, suggesting that the periods of supervised activity were the main contributors to the higher scores during the intervention period. However, the scores at week 18 were still higher than the other two groups.

The changes in pedometer scores were of such a magnitude that the previously determined mean overscore of 5.5% (95% CI 2.3 to 8.7) compared to counted steps probably had little influence on the results, although the latter was determined from walking on a treadmill rather than normal activity. The change in score for the control group at week 6 was similar to the coefficient of reliability (33.9%) and the results may have been attributed to changes in reliability of the pedometers. However, the other changes in pedometer scores, especially those of the exercise group, were of sufficient size to reflect actual changes in ambulatory activity rather than variation in pedometer function.

5.2 CHANGES IN HAEMODYNAMICS

5.2.1 CHANGES IN HEART RATE

Resting heart rate

At week 6 the resting heart rate (beats/min) was lower than at entry in all 3 groups (see Figure 5.5), but the percentage change from entry to week 6 showed a small increase in the control group, with an evenly distributed confidence interval (see Table 5.3). A decrease of approximately 8% was seen in both the exercise and education groups.

At week 18 all groups demonstrated a decrease compared to entry. Table 5.3 indicates the greatest reduction occurred in the education group and the least in the exercise group, but only small differences were seen between the medians of all 3 groups (see Table 5.4).

No differences were found in the pattern of change between the exercise and education group from entry to week 6.

Peak heart rate.

There were variable changes in mean peak heart rate (beats/min), the latter representing the highest heart rate achieved during a symptom limited exercise tolerance test. The rate for the education group remained constant across the three time points, (mean 98 [81 to 115] beats/min),whilst the exercise group maintained the same rate for entry and week 6 (91[71 to 111] beats/min) but increased by 9.9% to 100 (70 to 130) beats/min at week 18. The control group demonstrated the greatest variability in rate, ranging from 100 (88 to 112) beats/min at entry, to 103 (90 to 116) beats/min at week 6 and down to 93 (83 to 103) beats/min at week 18.

Figure 5.5 Resting heart rate (beats/min) at entry, week 6 and 18. Mean and 95% CI.

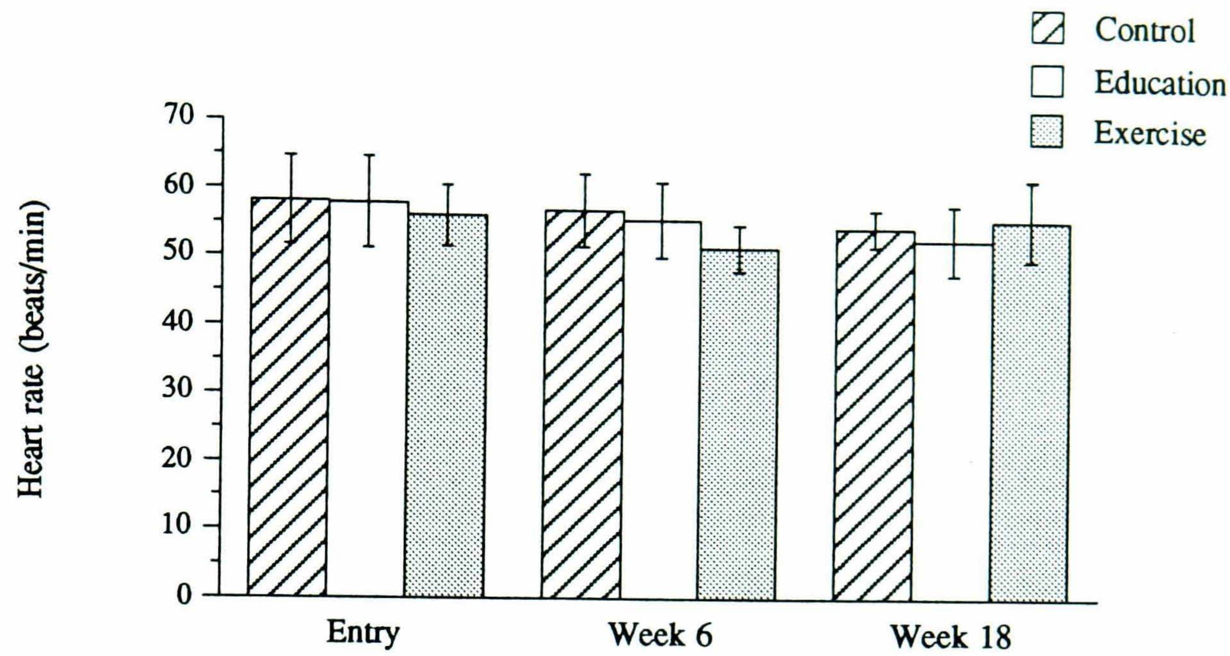


Table 5.3 Changes in resting heart rate expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	3.3%	-15.6 to 14.5	-3.6%	-23.1 to 10.8
Education	-8.9%	-16.7 to 13.7	-8.5%	-13.8 to 4.3
Exercise	-7.1%	-14.3 to 2.2	-1.0%	-22.3 to 18.6

A negative value indicates a decrease below entry value.

Table 5.4 Differences between the group medians for changes in resting heart rate.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-1.8%	-14.9 to 7.4	-2.9%	-13.9 to 9.1
Exercise - Control	3.5%	-10.2 to 7.4	-1.4%	-15.2 to 11.7
Education - Control	1.5%	-8.7 to 17.1	0.6%	-8.2 to 7.2

A negative value indicates the changes in the first group were less than the second group.

Heart rate at a sub-maximal load equivalent to 50% peak VO_2 at entry.

All groups demonstrated a progressive decrease in mean sub-maximal heart rate (beats/min) at week 6 and 18 (see Figure 5.6). When the change in rate was expressed as a percentage difference from entry, the exercise group demonstrated the largest decrease at both week 6 and 18, with the control group showing the least change (see Table 5.5). The differences between the exercise and education groups decreased over the study period, whilst those between the education and control groups increased (see Table 5.6).

No differences were found between the groups for the changes in sub-maximal rate at week 6 and 18.

When the pattern of change in sub-maximal heart rate (beats/min) for the education and exercise group were compared a significant difference was found between the two groups . Figure 5.7 below illustrates the sub-maximal heart rate in the exercise group decreased more quickly than that in the education group.

Figure 5.7 Changes in sub-maximal heart rate from entry to week 6.
Mean and 95% CI

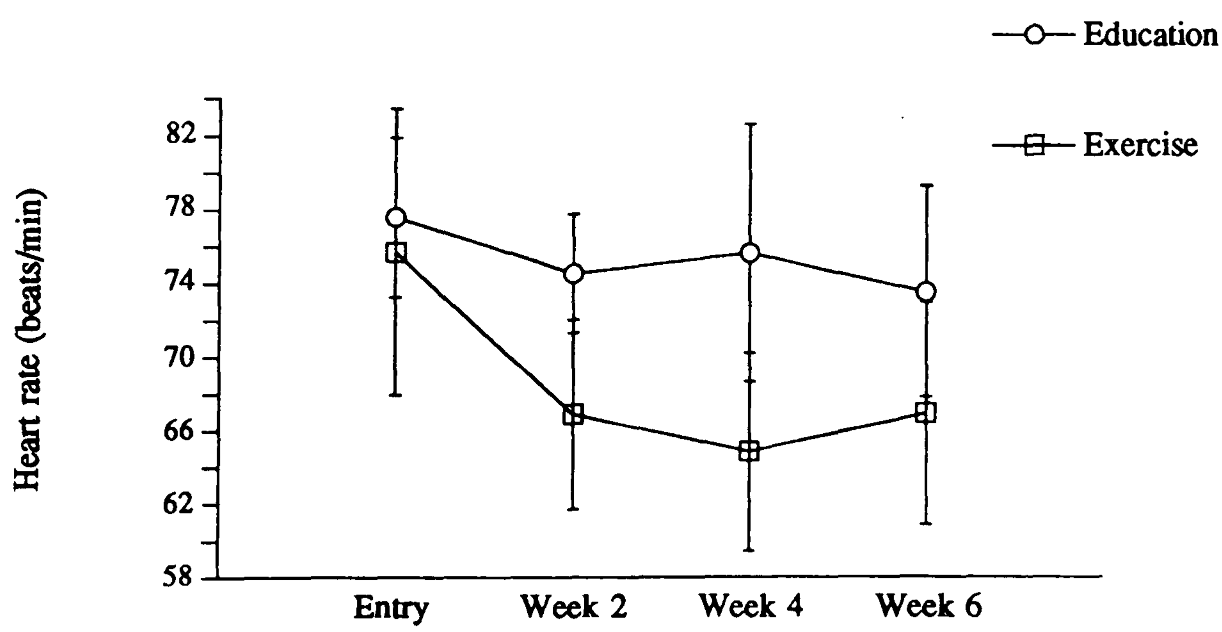


Figure 5.6 Heart rate at a sub-maximal load equivalent to 50% peak VO_2 uptake at entry. Mean and 95% CI.

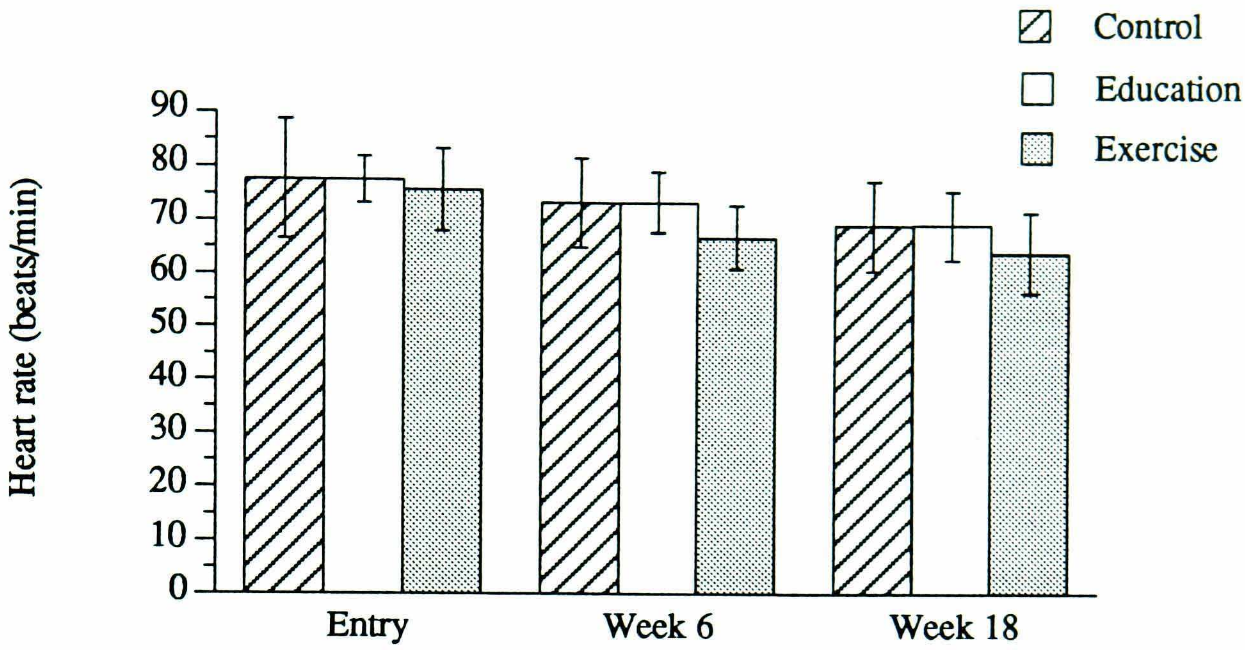


Table 5.5 Changes in sub-maximal heart rate expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	-3.9%	-11.3 to 3.5	-5.1%	-13.5 to 3.3
Education	-5.9%	-12.4 to 0.6	-10.3%	-17.3 to -3.3
Exercise	-11.5%	-18.1 to -4.9	-14.0%	-21.1 to -6.8

A negative value indicates an decrease in heart rate compared to entry.

Table 5.6 Differences between the group medians for changes in sub-maximal heart rate.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	5.6%	-4.2 to 15.3	3.7%	-7.0 to 14.3
Exercise - Control	7.6%	-2.7 to 17.9	8.9%	-5.2 to 22.9
Education - Control	2.2%	-1.5 to 8.7	5.7%	-3.1 to 13.4

A negative value indicates the changes in the first group were less than the second group.

Changes in heart rate at a fixed work load.

A variety of parameters were analysed at a fixed work load to provide further information on the inter-relationship between physiological changes.

The work load chosen was stage 03 of the treadmill protocol, which was completed by 12 patients in the control group and 15 in both the education and exercise groups.

The changes in heart rate (beats/min) at work load 03 of the modified Bruce protocol are shown in Figure 5.8. The heart rate generally decreased during the study period, although the control group did not show any changes until week 18. There were only small differences between the exercise and education group at week 6 and 18 (see Tables 5.7 and 5.8), with the largest difference occurring between the control and education group (12.4% [6 to 15.1]) at week 6.

5.2.2 CHANGES IN CARDIAC INDEX

Due to the longitudinal nature of the study the measurements of cardiac output were corrected for body mass and expressed as cardiac index ($L/min/m^2$).

The percentage increase of the investigated value above resting measurements was used in the analysis rather than the absolute score. The advantage of using this method rather than raw scores is that it takes into account any change in resting values during the study period.

Figure 5.8 Heart rate (beats/min) at stage 03 of treadmill protocol. Median and 95% CI.

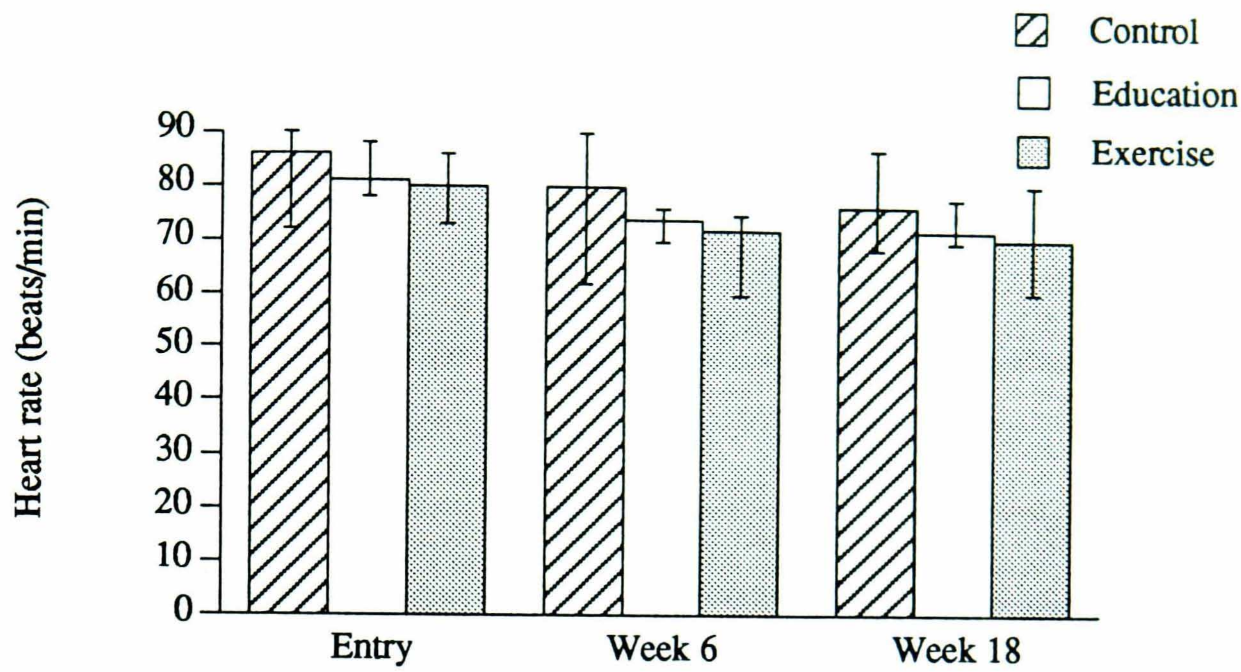


Table 5.7 Changes in heart rate at stage 03 treadmill protocol expressed as a percentage change from entry.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Control	0.0%	-18.4 to 7.1	-7.2%	-22.2 to 5.3
Education	-11.4%	-20.3 to 0.2	-10.9%	-19.1 to 0.0
Exercise	-8.5%	-25.9 to 0.8	-11.9%	-24.2 to 3.1

A negative value indicates a decrease in heart rate compared to entry.

Table 5.8 Differences between the group medians for changes in heart rate at stage 03.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-3.2%	-12.8 to 0.0	1.2%	-3.1 to 5.3
Exercise - Control	7.9%	6.1 to 11.9	4.5%	-5.2 to 9.8
Education - Control	12.4%	6.5 to 15.1	4.1%	-1.5 to 8.7

A negative value indicates the changes in the first group were less than the second group.

Changes in peak cardiac index

The peak cardiac index (L/min/m^2) at each time point is shown in Figure 5.9.

All 3 groups showed increases of approximately 12% from entry to week 6 (see Table 5.9) with large overlap of the 95% CI for the differences between the medians of the groups (see Table 5.10). At the end of the follow-up period the education group showed only a small further increase in peak cardiac index but large improvements were seen in both the exercise and control groups. At week 18 the changes in the exercise group were 8.7% (-38.2 to 50.3) larger than those in the control group, and 30.6% (-5.6 to 67.5) larger than in the education group.

None of these changes were significant.

Changes in cardiac index at sub-maximal loads.

The sub-maximal load used was the stage that corresponded with the penultimate cardiac output measurement at the time of entry for each individual patient. This was generally either stage 01 or 03 of the treadmill protocol.

Figure 5.10 shows the values for entry, week 6 and 18. Whilst the changes in raw scores suggest the cardiac index of the control group increased at week 6, Table 5.11 shows that the median value fell compared to entry when the individual measurements were expressed as a percentage change from the entry value. Both the exercise and education groups showed small increases in sub-maximal cardiac index, with that of the exercise group 7.1% (-27.3 to 46) greater than the education group (see Table 5.12).

Figure 5.9 Peak cardiac index (L/min/m^2) at entry, week 6 and 18.
Median and 95% CI.

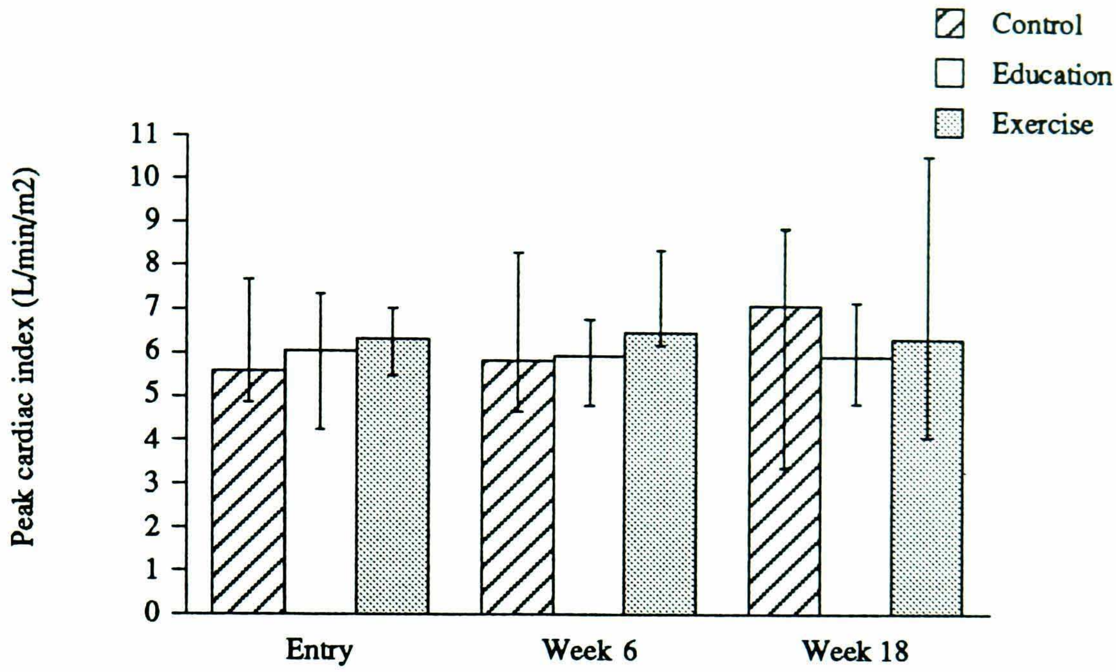


Table 5.9 Increase in peak cardiac index expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	10.7%	-9.5 to 53.5	37.7%	-25.8 to 162.8
Education	12.4%	-4.5 to 25.1	17.3%	-20.5 to 39.9
Exercise	11.9%	-5.7 to 57.4	35.1%	7.5 to 113.2

A negative value indicates a decrease below entry value.

Table 5.10 Differences between the group medians for changes in peak cardiac index.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	5.9%	-16.5 to 35.1	30.6%	-5.6 to 67.5
Exercise - Control	6.1%	-22.0 to 44.9	8.7%	-38.2 to 50.3
Education - Control	1.6%	-28.8 to 25.1	-21.1%	-58.2 to 17.1

A negative value indicates the changes in the second group were greater than those in first group.

Figure 5.10 Cardiac index (L/min/m^2) at sub-maximal loads.
Median and 95% CI.

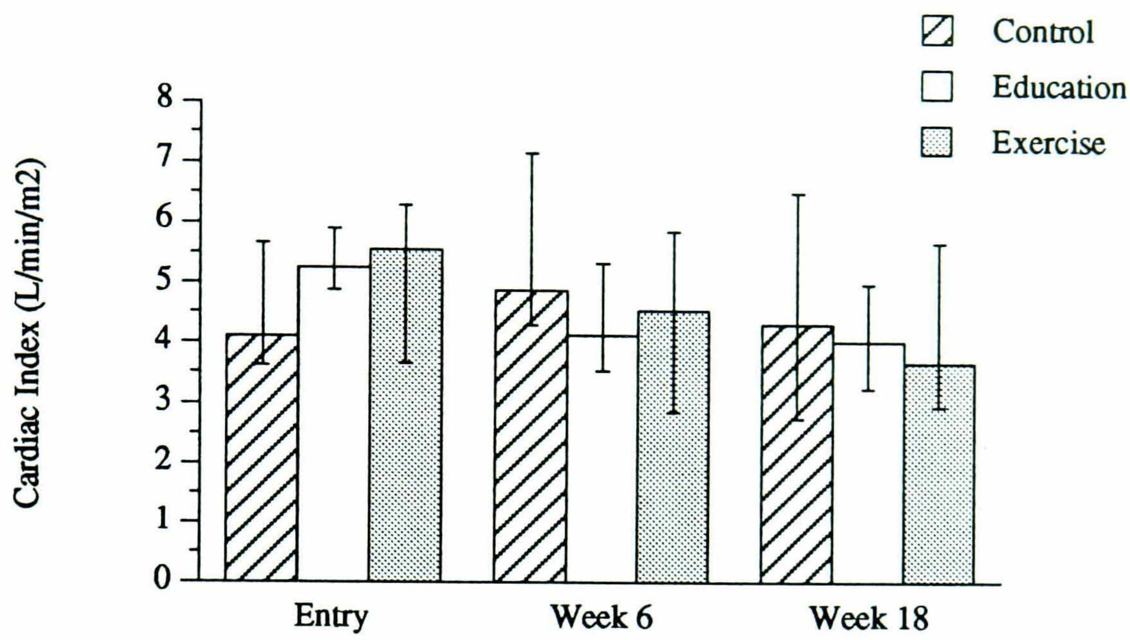


Table 5.11 Changes in cardiac index at sub-maximal loads expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	-7.7%	-19.5 to 28.5	9.8%	-41.5 to 28.8
Education	1.6%	-32.4 to 30.5	-5.8%	-37.5 to 15.1
Exercise	7.7%	-49.5 to 63.1	5.4%	-54.7 to 38.3

A negative value indicates a decrease in cardiac index compared to entry.

Table 5.12 Differences between the group medians for changes in sub-maximal cardiac index.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	7.1%	-27.3 to 46.2	11.1%	-9.7 to 37.7
Exercise - Control	6.1%	-33.2 to 37.3	-0.5%	-23.4 to 28.7
Education - Control	-6.2%	-26.5 to 14.6	-10.9%	-31.7 to 7.6

A negative value indicates the changes in the first group were less than the second group.

At week 18 the cardiac index decreased below entry level in the education group, with a small difference (0.5%, -23.4 to 28.7) between the increases in the control and exercise groups.

Changes in cardiac index at a fixed work load

A variety of parameters were measured at a fixed work load to provide further information on the inter-relationship between physiological changes.

The results for changes in cardiac index (L/min/m^2) are shown in Figure 5.11.

At both week 6 and 18 the cardiac index increased in the control group whilst it hardly changed in the other two groups (see Table 5.13), but the confidence intervals were wide. There were only small differences of approximately 1% between the changes in the education and exercise groups, as shown in Table 5.14.

No significant differences were found between the groups for any changes in cardiac index.

5.2.3 DISCUSSION OF CHANGES IN CENTRAL HAEMODYNAMICS

Changes in resting heart rate.

In the early weeks of recovery, attendance at the rehabilitation programme appeared to confer a reduction in resting heart rate. However, this was not influenced by participation in the supervised exercise programme as there was only a small difference between the changes in the exercise and education group. This suggests the reduction may have a psychological basis, but the changes in anxiety do not relate to the changes in resting

Figure 5.11 Cardiac index (L/min/m2) at stage 03 of treadmill protocol. Median and 95% CI.

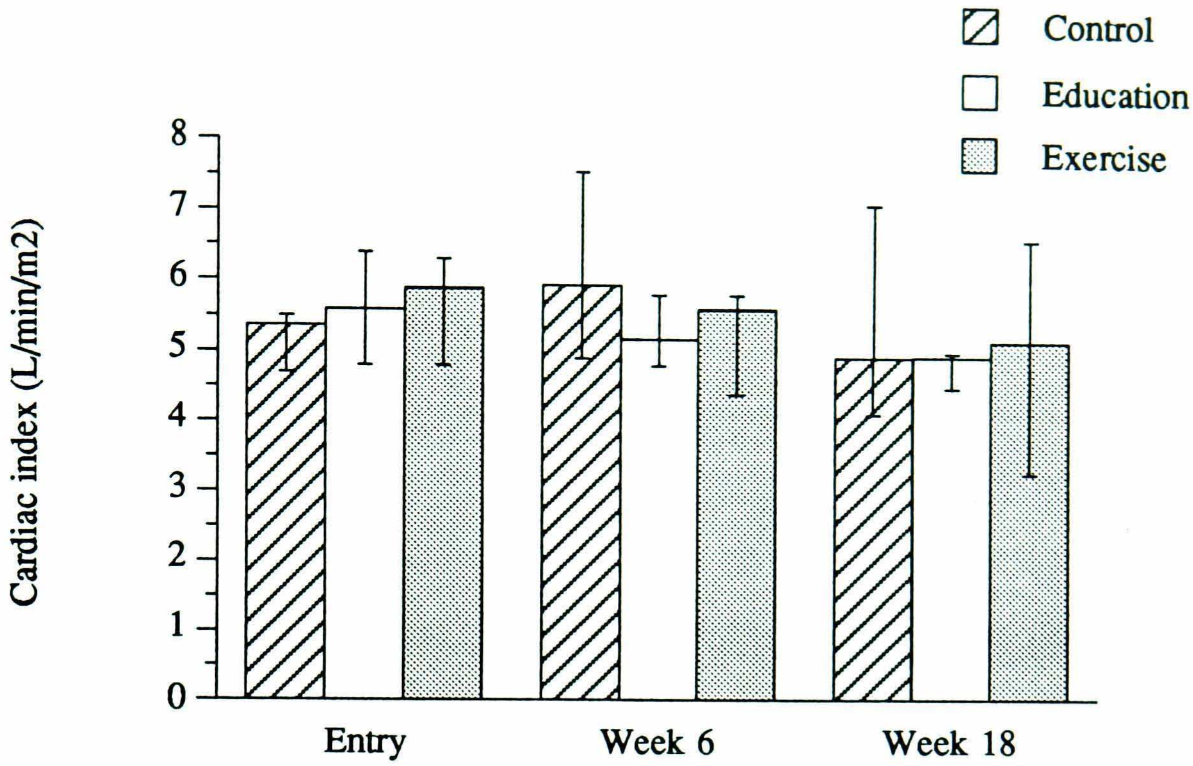


Table 5.13 Changes in cardiac index at stage 03 treadmill protocol expressed as a percentage change from entry.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Control	11.1%	-37.1 to 28.9	16.3%	-26.4 to 29.7
Education	2.3%	-32.5 to 57.3	-0.4%	-39.3 to 39.4
Exercise	1.9%	-36.8 to 50.1	0.5%	-26.0 to 59.1

A negative value indicates a decrease in cardiac index compared to entry.

Table 5.14 Differences between the group medians for changes in cardiac index at stage 03.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-0.6%	-24.3 to 36.7	1.4%	-18.6 to 25.8
Exercise - Control	-12.3%	-33.1 to 24.5	-17.4%	-23.0 to 31.3
Education - Control	-9.2%	-21.1 to 23.4	-17.3%	-25.1 to 22.6

A negative value indicates the changes in the first group were less than the second group.

heart rate. The education and control groups experienced similar decreases in anxiety at week 6, and there was a large difference between the changes in both of these groups and the decrease in anxiety shown by the exercise group.

The increase in resting rate shown by the control group at week 6 may have been due to anticipatory psychological stimulation prior to performing the exercise tolerance test. This group did not perform the exercise test at week 2 and 4 and so were less familiar with the laboratory environment and had received less feed-back on their progress than the other two groups. This may have been translated into a faster resting heart rate. By week 18 the control group may have felt sufficiently confident with their recovery not to be affected by the procedure.

Changes in peak values.

The increases of approximately 12% in peak cardiac index for all groups at week 6 suggests that it reflects the spontaneous recovery of cardiac function in the early stages of recovery after a MI. Although the median values were accompanied by wide confidence intervals, the latter were attributable to large increases in cardiac index.

Both the control and exercise groups showed further improvements in peak cardiac index at week 18, in contrast to the small change in the education group. The difference of 8.7% (-38.2 to 50.3) between the increase in the control and exercise group suggests that completion of the rehabilitation programme (exercise and education sessions) has a small affect on peak cardiac index. However, comparison of the confidence intervals for the median increase in peak cardiac index (Table 5.9) show that all the patients in the exercise group experienced an improvement in cardiac index, whilst it decreased in some of the patients in the control group.

The small improvement in the education only group is difficult to explain. The characteristics of the patients were similar on entry (see Table 4.1) and it would be expected that changes in peak cardiac index would be at least as good as those seen in the control group.

The improvements in peak cardiac index seen in all the groups were larger than the 3% difference between repeated measurements determined prior to the main study and described in Chapter 4.3.2. Consequently the changes in the results are likely to be attributable to changes in physiological state rather than variation in measurement technique. Unfortunately, due to the design of the protocol, it was not always possible to measure cardiac output at the time of cessation of the exercise test. In some patients this resulted in an under-estimation of their peak value when they terminated the test during a stage when measurement of cardiac output was not performed. The alternative, the performance of a rebreathing manoeuvre at the end of the test irrespective of the stage of protocol, was not felt to be appropriate with this group of patients in the early stage of recovery after an MI.

The increase in peak heart rate shown by the exercise group at week 18 is interesting. When a maximum exercise tolerance test is not performed the point of voluntary termination is influenced by the patient's perception of the intensity of the exercise. This increase probably reflects the patient's increased confidence, which allowed them to exercise to a higher level of intensity. However, there is considerable overlap of the confidence intervals for peak heart rate at entry, week 6 and 18, indicating the increase did not occur in all patients.

Changes in sub-maximal values.

The changes at 50% peak VO_2 sub-maximal load and the fixed sub-maximal work load yielded differing results.

All of the sub-maximal sets of results for changes in cardiac index showed wide confidence intervals which may partially explain the apparent contradictory physiological responses. The physiological demands of working at the fixed work load would be different for each patient, with some working closer to peak levels than others, and this may also have contributed to the differences between the results.

The most marked effects of the exercise programme were seen in the rate of decrease in heart rate between entry and week 6 for the work performed at 50% peak VO_2. Whilst none of the other differences between the groups reached significance levels, those of the exercise group were sufficiently large to indicate the presence of a training effect. This was supported by the significant difference between the education and exercise groups for the pattern of decrease in sub-maximal heart rate, with the exercise group showing a faster reduction in heart rate. These changes indicate that patients who participated in the exercise programme derived early benefits in a decrease in sub-maximal heart rates. However, the exercise group also showed an increase in sub-maximal cardiac index, which suggests a training effect had not occurred, but this was accompanied by wide confidence intervals.

The results from the fixed work load suggest the demand on the cardiovascular system of the control group increased at week 6 and 18 compared to entry, as shown by the rise in cardiac index. This group did not show the decrease in sub-maximal heart rate at week 6 seen in the other 2 groups, probably as a result of trying to meet the increased demand in cardiac output. At week 18 the heart rate fell despite a further increase in cardiac index, suggesting the increased demand was met by a larger stroke volume. The possible deterioration of cardiovascular function in the control patients was supported by the increase in cardiac index at the sub-maximal load at week 18 but not week 6, where the median value fell below entry level, indicating an improvement in function.

Overall, these results show that whilst participation in the rehabilitation programme did not influence changes in cardiac index it did appear to have a beneficial influence on heart rate.

5.2.4 CHANGES IN LIMB BLOOD FLOW

Resting blood flow.

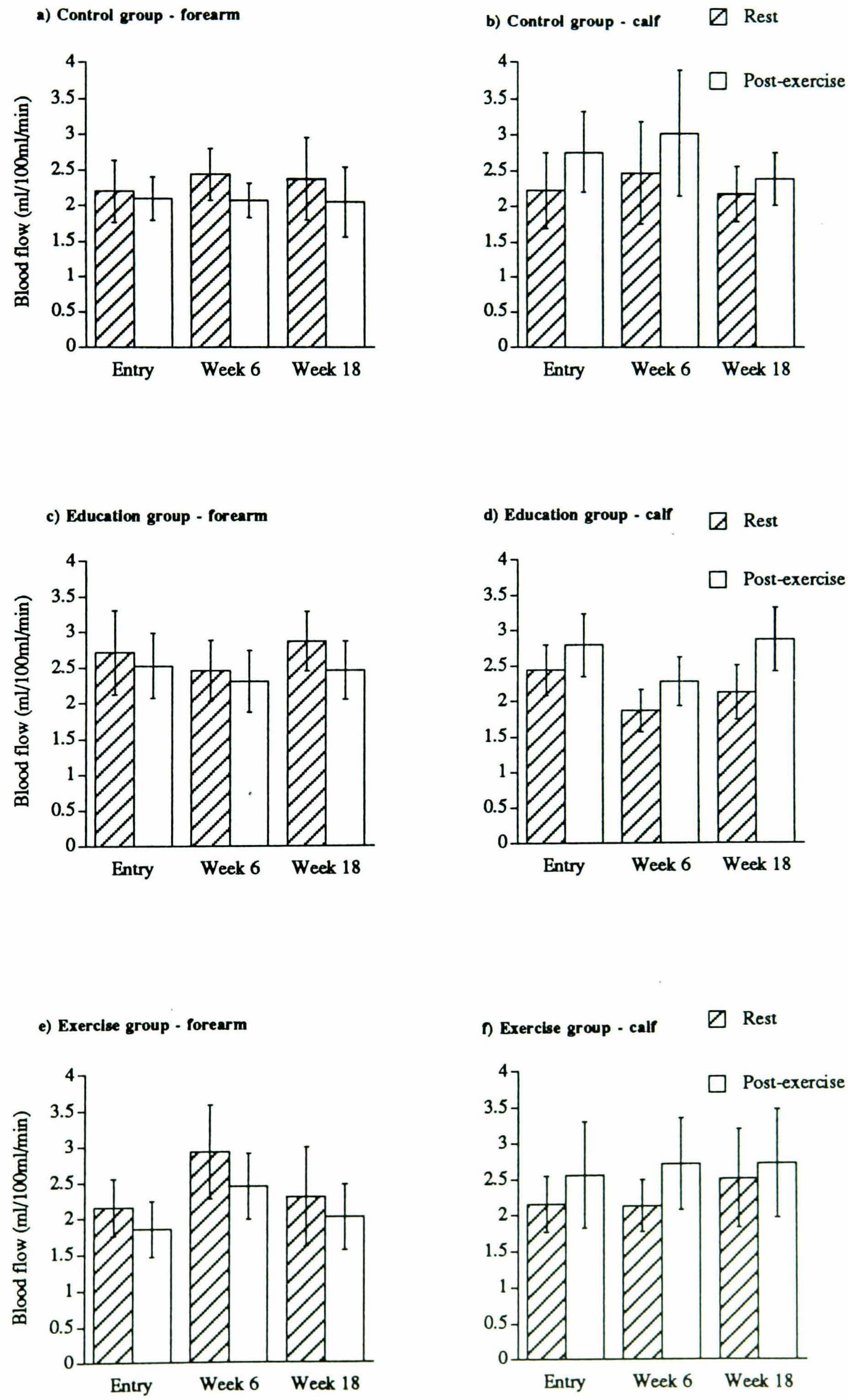
At rest the blood flow in the lower leg was similar or less than that in the forearm for each group at all 3 time points (see Figure 5.12 a-f). Only small differences in blood flow were seen between the groups over the 18 weeks.

The largest difference in forearm blood flow occurred between the education and exercise group at entry, with a mean difference of 0.56 ml/100ml/min (-0.2 to 1.4). The maximum difference for lower leg blood flow was found at week 6 between the control and education groups (0.55 ml/100 ml/min [-0.3 to 1.2]).

Post sub-maximal exercise blood flow

The changes in lower leg and forearm blood flow immediately after sub-maximal exercise are shown in Figure 5.12 a-f. In all groups the blood flow to the lower leg increased immediately after exercise, whilst that to the forearm decreased. The change in flow between the lower leg and

Figure 5.12 Changes in lower leg and forearm blood flow (ml/100ml/min) at rest and 3 minutes after sub-maximal exercise. Mean and 95% CI.



forearm did not follow a linear relationship, with the highest correlation for any of the groups only reaching r_S -0.4.

Comparisons of the increase in peak lower leg blood flow above resting values, expressed as a percentage of the entry measurement, showed greater blood flows at week 6 and 18 in the exercise and education groups, but reduced peak flows in the control group (see Table 5.15). The difference between the control and other groups for changes in peak blood flow were significant at week 18 (see Table 5.16).

Over the study period in all groups the reduction in forearm blood flow after exercise was less at week 6 and 18 than at entry.

Changes in the mean post exercise blood flow in the lower leg are shown in Figure 5.14. The education and control groups did not show any consistent changes at week 6 and 18 when compared to entry (see Table 5.17), but the exercise group showed a progressive increase in flow over the study period. At week 6 there were large differences between the education and other 2 groups, and between the control and other groups at week 18 (see Table 5.18). None of these differences reached significance, probably due to their large confidence intervals.

The mean forearm blood flow in the control group hardly changed over the weeks. There were small decreases in the education group at week 6 and 18 (5% [-19 to 31] and 2.5% [-23 to 34] respectively) compared to entry. In contrast, the exercise group showed increases in forearm flow at week 6 and 18 (33.2% [7 to 57] and 9.2% [-15 to 34] respectively).

Figure 5.13 Peak post-exercise calf blood flow expressed as a percentage above resting value. Mean and 95% CI.

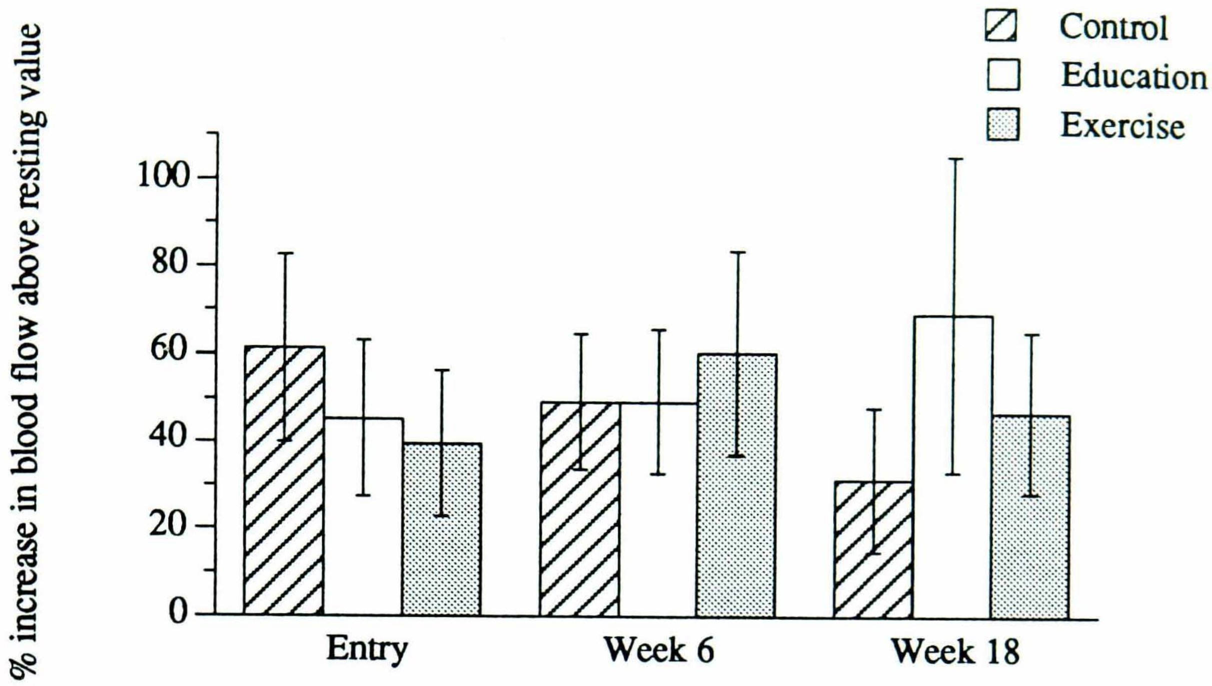


Table 5.15 Changes in peak lower leg blood flow after sub-maximal exercise, determined as increase above rest, and expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18*	
	Median	**95% CI**	**Median**	**95% CI**
Control	-9.1%	-27.6 to 18.2	-21.5%	-52.5 to 9.8
Education	7.4%	-20.7 to 48.5	20.8%	-17.3 to 160.1
Exercise	4.4%	-25.4 to 34.2	3.5%	-30.0 to 73.2

A negative value indicates a decrease in blood flow compared to entry.

*$p < 0.01$ for differences between groups from entry to week 18

Table 5.16 Differences between the group medians for changes in peak lower leg blood flow.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-5.4%	-28.3 to 21.6	-12.7%	-46.2 to 10.9
Exercise - Control	-10.3%	-14.1 to 32.2	-34.3% *	-57.1 to -9.6
Education - Control	20.3%	-6.2 to 40.0	44.2% *	27.3 to 69.5

A negative value indicates the changes in the first group were less than the second group.

* $p < 0.05$

Figure 5.14 Changes in mean post-exercise lower leg blood flow (ml/100ml/min). Mean and 95% CI.

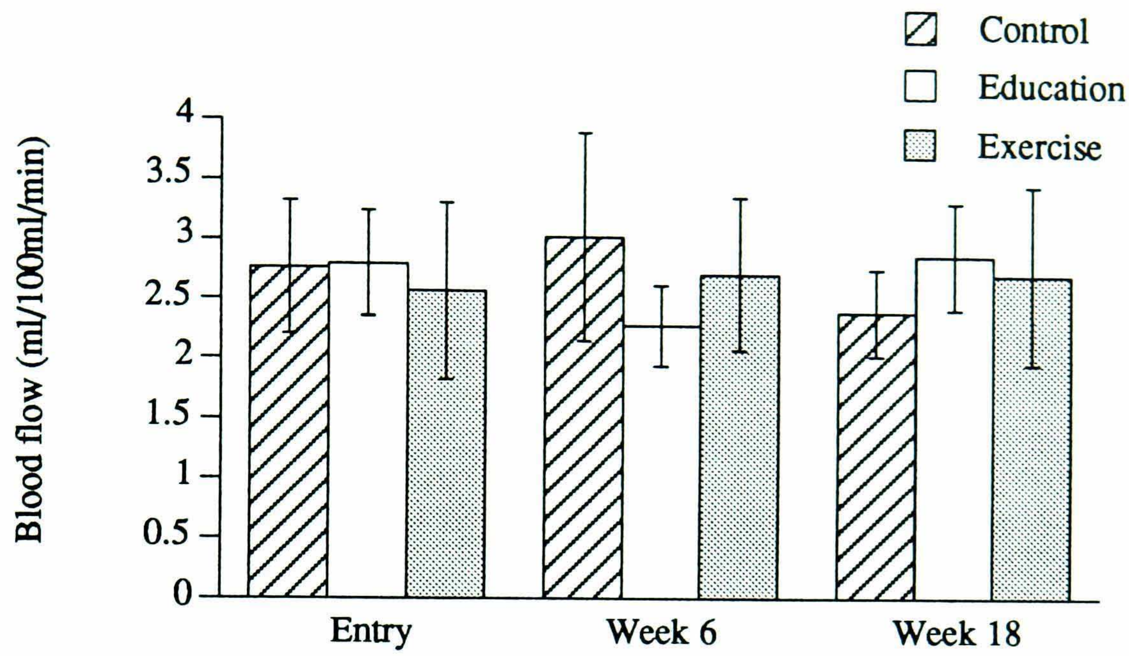


Table 5.17 Changes in mean lower leg blood flow post sub-maximal exercise, expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	4.1%	-31.2 to 42.3	-11.1%	-37.6 to 73.1
Education	-15.8%	-30.1 to 11.8	17.3%	-19.4 to 33.8
Exercise	6.8%	-11.1 to 31.3	19.5%	-9.1 to 49.3

A negative value indicates a decrease in blood flow compared to entry.

Table 5.18 Differences between the group medians for changes in mean lower leg blood flow.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-20.5%	-22.4 to 10.8	3.4%	-22.5 to 18.3
Exercise - Control	1.8%	-15.4 to 14.3	31.4%	-15.2 to 53.7
Education - Control	18.4%	-20.6 to 31.2	26.5%	-12.4 to 45.3

A negative value indicates the changes in the first group were less than the second group.

5.2.5 DISCUSSION OF CHANGES IN LIMB BLOOD FLOW

The changes in blood flow observed at rest in both the forearm and lower leg were within their previously determined coefficients of reliability (1.68 ml/100ml/min and 0.76 ml/100ml/min respectively) for repeated measurements. This implies the results may not have been due to changes in blood flow, but arose due to the variation in serial measurements.

The difference between the control and other groups for changes in peak lower leg blood flow after sub-maximal exercise may be attributable to changes in the working muscle. Healthy subjects who undergo aerobic training demonstrate a decrease in muscle blood flow/kg of active muscle (Astrand and Rodahl 1986; Fox and Matthews 1981).

The decline in increased peak blood flow in the control group may have been the result of increased oxygen extraction within the active muscles, indicating an improvement in aerobic function. At week 6 this group also showed a decrease in sub-maximal cardiac index, supporting the theory of an increase in oxygen extraction from blood.

Alternatively, the patients in the education and exercise groups may have experienced an increase in muscle tissue and capillarity of the lower leg which increased the total mass of the region. This would explain the continued increase in peak sub-maximal blood flow for the lower leg. Whilst the measurements of blood flow were expressed as flow/100ml tissue/min, changes in the circumference of the limb were determined by a tape-measure and any new measurement used in the calculation of blood flow. However this is an imprecise method of determining muscle mass and the error may have masked any changes in blood flow/kg of muscle. If an increase in muscle bulk had occurred it may help to explain the increase in sub-maximal cardiac index seen in these groups at week 6.

Other measurements of muscle mass or arterio-venous oxygen difference would be required to lend support to either of these statements, but these were not available in this laboratory.

Given the possible explanation above for the increased peak blood flow in the education and exercise groups, the reason for the greater increase in peak blood flow seen in the education group at week 18 compared to the exercise group is not obvious. The education group did not undertake a formal training programme, which may have been expected to increase muscle bulk, and their pedometer scores were less than the exercise group. The education group may have been more active between week 6 and 18, with a concomitant increase in the mass of the calf.

At both week 6 and 18 the increase in peak lower leg blood flow seen in the exercise group after sub-maximal exercise was accompanied by an increase in mean post-exercise blood flow. This suggests an increase in sub-maximal cardiac output, which was observed at both weeks for the 50% VO_2 work load, but not at week 18 for the fixed work load. However the changes in mean blood flow were within the range of the coefficient of reliability (0.78ml/100ml/min) and therefore may be influenced more by variation in serial measurements than actual changes in blood flow.

The decrease in forearm blood flow immediately after exercise shown by all groups indicates that the increased flow in the lower leg is at least partially due to redistribution of blood from inactive forearm muscles. The increase in mean post-exercise forearm blood flow at week 6 and 18 compared to entry seen in the exercise group was probably due to the increase in sub-maximal cardiac output.

Participation in the exercise programme did not appear to influence oxygen extraction as determined by changes in blood flow after sub-maximal exercise

5.3 CHANGES IN RESPIRATORY MEASUREMENTS

5.3.1 CHANGES IN OXYGEN CONSUMPTION

Peak oxygen uptake.

All groups showed an improvement in oxygen uptake during the study and the increases in peak VO_2 uptake from rest, expressed as METs, are shown in Figure 5.15.

Although Figure 5.15 shows the control group demonstrated the largest increase in oxygen uptake at week 6, when the medians for the individual changes within each group were determined (see Table 5.19), both the education and exercise groups demonstrated larger gains than the control group. Comparisons of the differences between the medians at week 6 (see Table 5.20) show a small difference between the exercise and education group, but larger differences between the control and other two groups. This situation altered at week 18, with large differences between the changes in the exercise group and the other two groups, whilst that between the education and control groups hardly changed.

When the sample was analysed collectively there was a significant inverse linear relationship between the entry level of peak VO_2 uptake and its increase during the study period. At week 6 the correlation coefficient was r_s -0.48 and r_s -0.5 at week 18.

Figure 5.15 Changes in peak METs.

Median and 95% CI

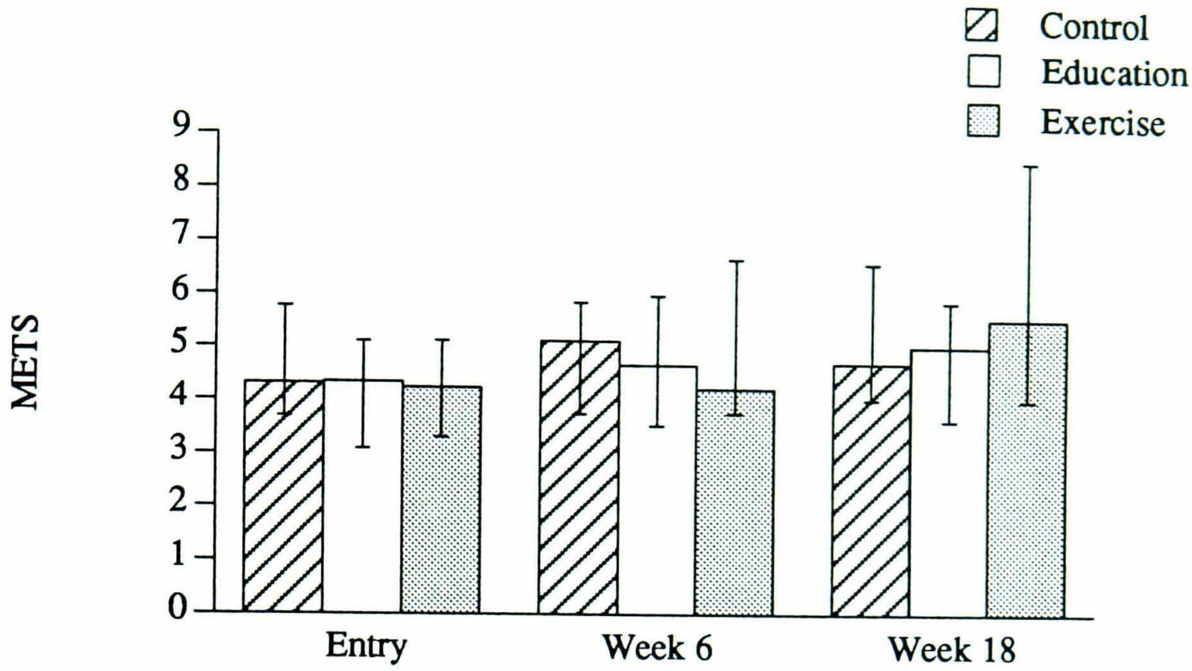


Table 5.19 Changes in peak METs expressed as a percentage change from entry.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Control	5.1%	-4.5 to 14.7	12.5%	-4.2 to 53.1
Education	13.5%	-5.7 to 42.3	16.5%	-7.7 to 49.0
Exercise	15.5%	-10.0 to 34.5	40.1%	11.4 to 58.4

A negative value indicates a decrease in value compared to entry.

Table 5.20 Differences between the group medians for changes in peak METs.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	5.1%	-27.5 to 24.1	20.5%	-6.7 to 37.2
Exercise - Control	10.1%	-12.1 to 26.9	28.7%	-8.8 to 44.3
Education - Control	7.2%	-13.4 to 27.4	4.1%	-19.3 to 32.1

A negative value indicates the changes in the first group were less than the second group.

No difference was found for the pattern of change of peak METs between the exercise and education groups at entry and weeks 2, 4 and 6.

Oxygen uptake at a sub-maximal load equivalent to 50% peak VO_2 at entry

The changes in oxygen uptake at this sub-maximal load are shown in Figure 5.16.

The exercise group showed a large decrease in oxygen uptake at both week 6 and 18, with the control group showing only small decreases (see Table 5.21). In contrast, the education group showed increases at both time points, although that at week 18 was approximately half the increase at week 6.

The difference between the education and exercise groups was significant at week 6. No significant differences were found at week 18.

Changes in oxygen consumption at a fixed work load

Figure 5.17 shows the changes in oxygen uptake at stage 03. These changes were smaller than those seen for the work load at 50% peak VO_2.

The largest changes were seen at week 6, with decreases in O_2 consumption for both the education and exercise groups (see Table 5.23). At week 18 the control group showed a small decrease compared to entry but the values for the other two groups were similar to those at entry.

All the changes were accompanied by wide confidence intervals and no differences were found between the groups.

Figure 5.16 METs at sub-maximal load equivalent to 50% peak VO_2 at entry. Median and 95% CI.

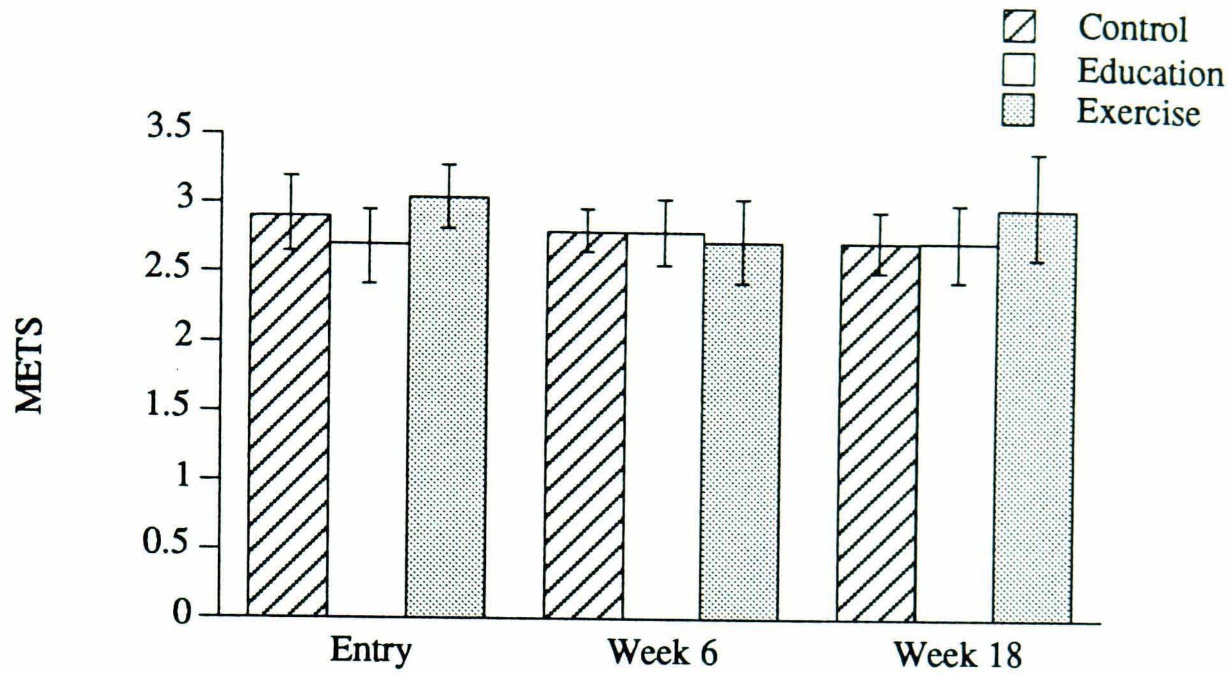


Table 5.21 Changes in METs at 50% peak VO_2 work load expressed as a percentage change from entry.

	Entry to Week 6*		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	-3.9%	-13.2 to 19.1	-2.3%	-24.5 to 21.2
Education	8.0%	-12.7 to 25.2	4.7%	-27.3 to 43.0
Exercise	-13.6%	-20.8 to 2.7	-12.0%	-32.6 to 29.8

A negative value indicates a decrease compared to entry.

*$p<0.05$ between the groups at week 6.

Table 5.22 Differences between the group medians for changes in sub-maximal METs.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	5.8%*	-4.2 to 10.1	7.9%	-14.2 to 25.4
Exercise - Control	10.2%	-12.7 to 20.3	9.4%	-12.9 to 18.2
Education - Control	3.9%	-11.1 to 25.4	2.6%	-11.4 to 23.1

A negative value indicates the changes in the first group were less than the second group.

*$p <0.05$

Figure 5.17 METs at stage 03 treadmill protocol.
Median and 95% CI.

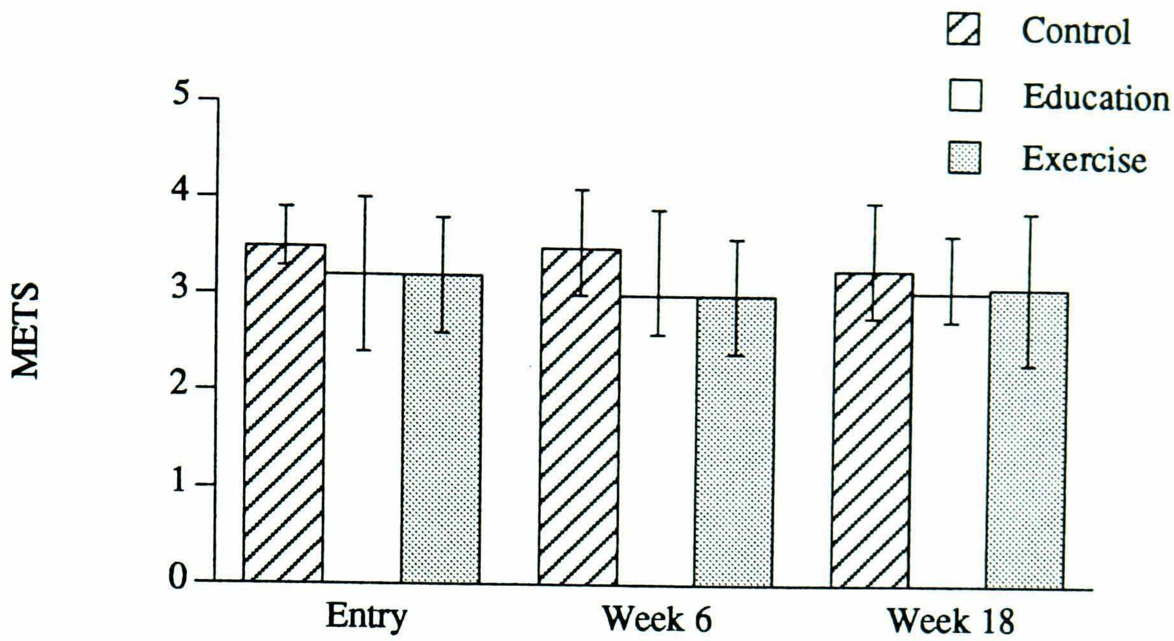


Table 5.23 Changes in METs at treadmill stage 03 expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	5.1%	-21.5 to 7.3	-3.4%	-44.8 to 77.1
Education	-9.1%	-22.1 to 28.3	0.2%	-15.6 to 25.5
Exercise	-4.6%	-20.9 to 23.2	-0.5%	-30.1 to 30.3

A negative value indicates a decrease compared to entry.

Table 5.24 Differences between the group medians for changes in METs at treadmill stage 03

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-5.4%	-16.2 to 14.3	0.4%	-11.8 to 9.5
Exercise - Control	-1.4%	-13.1 to 14.1	-3.1%	-12.4 to 15.3
Education - Control	3.9%	-8.7 to 18.5	-3.1%	-15.9 to 21.2

A negative value indicates the changes in the first group were less than the second group.

5.3.2 CHANGES IN MINUTE VENTILATION

Changes in peak minute ventilation.

The changes in peak minute ventilation are shown in Figure 5.18.

When the percentage differences from entry to weeks 6 and 18 were compared the median value for each group fell below that of the entry level. At week 6 the largest fall was seen in the control group and the least in the education group, with the positions reversed at week 18 (see Table 5.25).

There were large differences between the medians for the exercise and other two groups at week 18 (see Table 5.26) but they were not significant.

No difference was found for the pattern of change between the education and exercise groups for entry, week 2, 4 and 6.

Minute ventilation at a sub-maximal load equivalent to 50% peak $V0_2$ at entry.

The changes in minute ventilation at this sub-maximal work load are shown in Figure 5.19.

All groups showed a decrease in minute ventilation at both week 6 and 18 compared to entry (see Table 5.27). At week 6 the largest decrease was seen in the education group (17.7%) and the least in the control group (11.8%). At week 18 the changes in the control and education groups only slightly altered from those at week 6 but there was a further decrease in minute ventilation in the exercise group.

The largest differences between the groups for these changes occurred at week 18 (see Table 5.28). There was a small difference between the

Figure 5.18 Changes in peak minute ventilation (L/min).
Median and 95% CI.

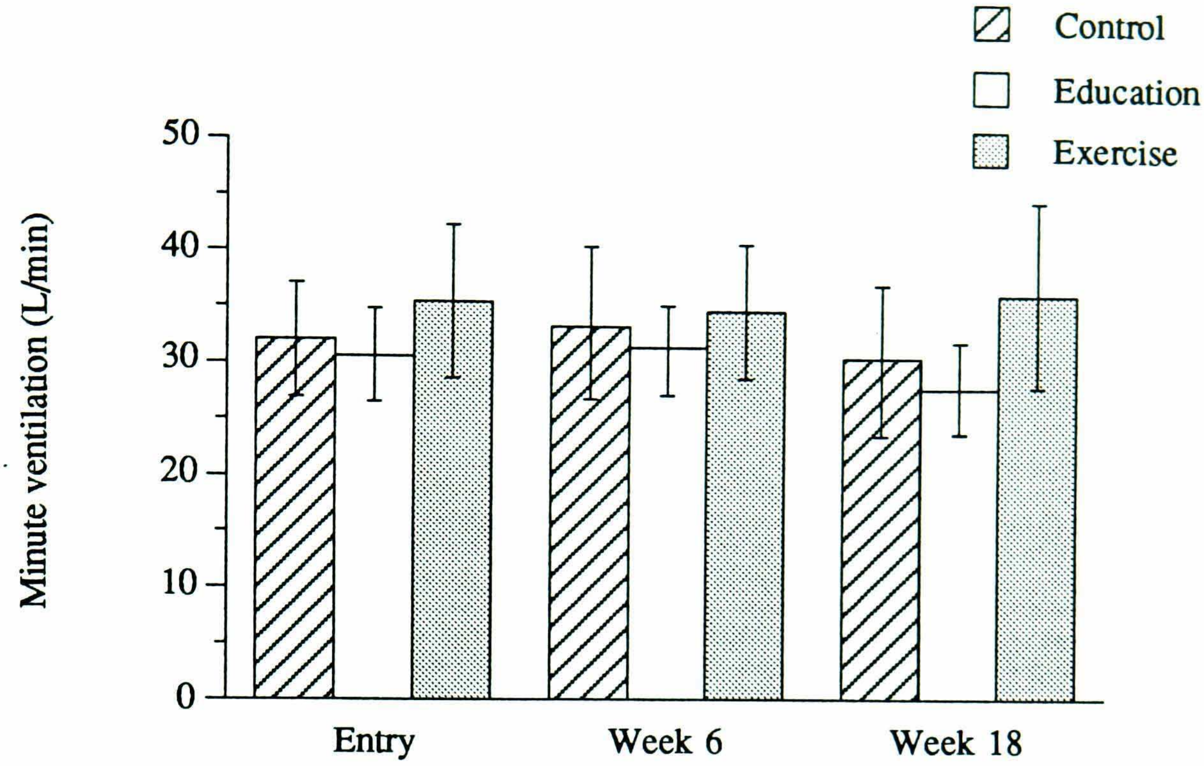


Table 5.25 Changes in peak minute ventilation expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	-8.4%	-33.5 to 93.5	-0.2%	-49.1 to 40.2
Education	-1.3%	-30.5 to 23.0	-6.4%	-19.8 to 42.9
Exercise	-4.5%	-19.2 to 52.2	-1.7%	-38.1 to 51.6

A negative value indicates a decrease compared to entry.

Table 5.26 Differences between the group medians for changes in peak VE.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	2.5%	-22.7 to 24.9	-14.7%	-43.1 to 10.4
Exercise - Control	-6.1%	-27.7 to 35.8	17.1%	-9.6 to 43.9
Education - Control	-3.4%	-38.8 to 14.6	7.4%	-28.8 to 9.9

A negative value indicates the changes in the first group were less than the second group.

education and exercise group, but greater differences between these groups and the control group.

Changes in minute ventilation at a fixed work load

The changes for minute ventilation at stage 03 of the treadmill protocol are shown in Figure 5.20.

These followed the pattern of changes seen for the previous sub-maximal work load, with all groups showing a decrease in minute ventilation at week 6 and 18 compared to entry.

The exercise and control groups showed similar changes at week 6 (see Table 5.29 and 5.30), with the greatest decrease (14.4%) occurring in the education group. The minute ventilation continued to fall at week 18, with the education and control groups showing only modest changes since week 6, but the exercise group showed a 24.6% decrease from entry and over a 100% change from the decrease seen at week 6.

5.3.3 CHANGES IN THE RELATIONSHIP BETWEEN MINUTE VENTILATION AND CARBON DIOXIDE PRODUCTION

Plots of minute ventilation (L/min) and carbon dioxide production (ml/kg/min) were drawn for each subject at entry, week 6 and 18 (see Figure 5.21) using the all the data points from the exercise tests.

The slope of the plots were determined and the changes are shown in Figure 5.22.

At week 6 all 3 groups showed a reduction in the gradient of the slope (see Table 5.31 with similar differences between the medians of the groups

Figure 5.19 Minute ventilation at sub-maximal load equivalent to 50% peak VO_2 at entry. Median and 95% CI.

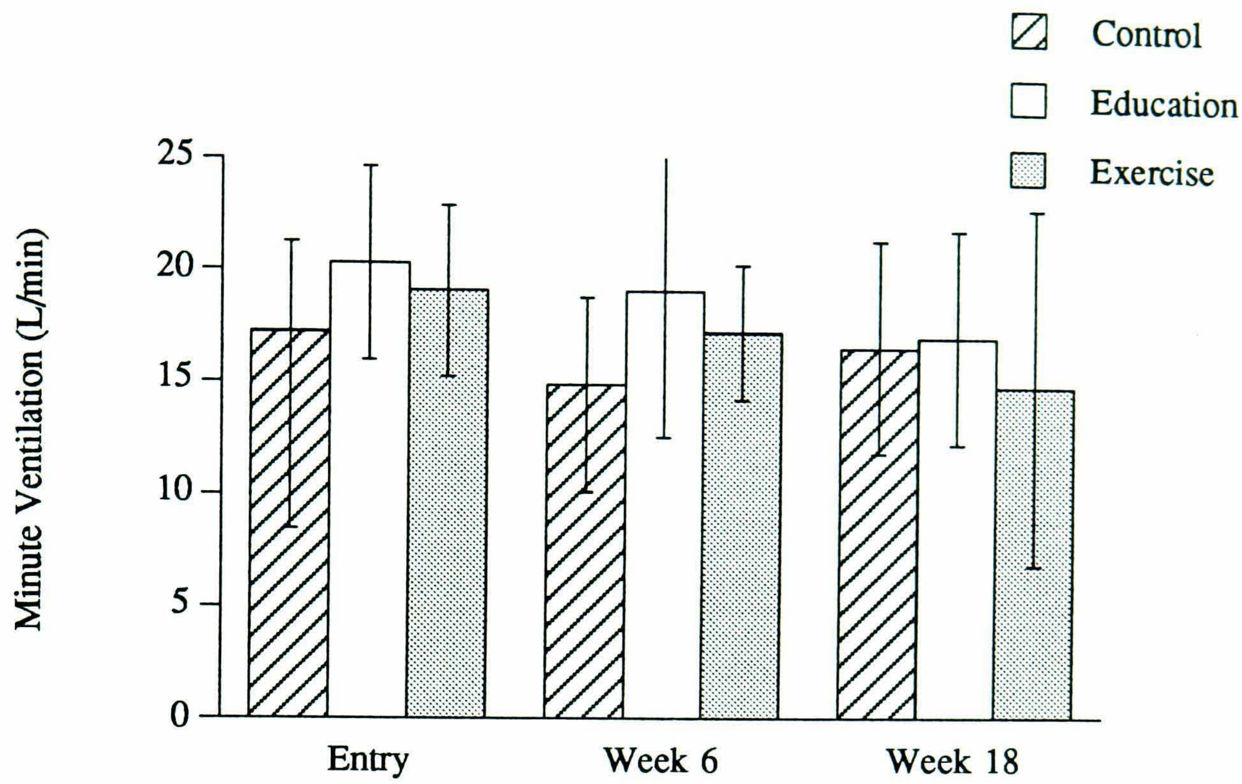


Table 5.27 Changes in VE at work load equivalent to 50% peak VO_2 at entry, expressed as a percentage change from entry.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Control	-11.8%	-19.7 to 18.8	-12.1%	-40.3 to 30.7
Education	-17.7%	-27.4 to 0.0	-19.4%	-35.9 to 37.8
Exercise	-15.3%	-22.7 to -2.5	-24.1%	-36.1 to 13.3

A negative value indicates a decrease compared to entry.

Table 5.28 Differences between the group medians for changes in VE.

	Entry to Week 6		**Entry to Week 18**	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-3.6%	-14.5 to 15.3	4.8%	-13.2 to 21.4
Exercise - Control	3.1%	-12.9 to 24.5	10.3%	-14.6 to 28.1
Education - Control	6.4%	-13.8 to 28.3	8.2%	-12.7 to 25.4

A negative value indicates the changes in the first group were less than the second group.

Figure 5.20 Minute ventilation (L/min) at stage 03 treadmill protocol. Median and 95% CI

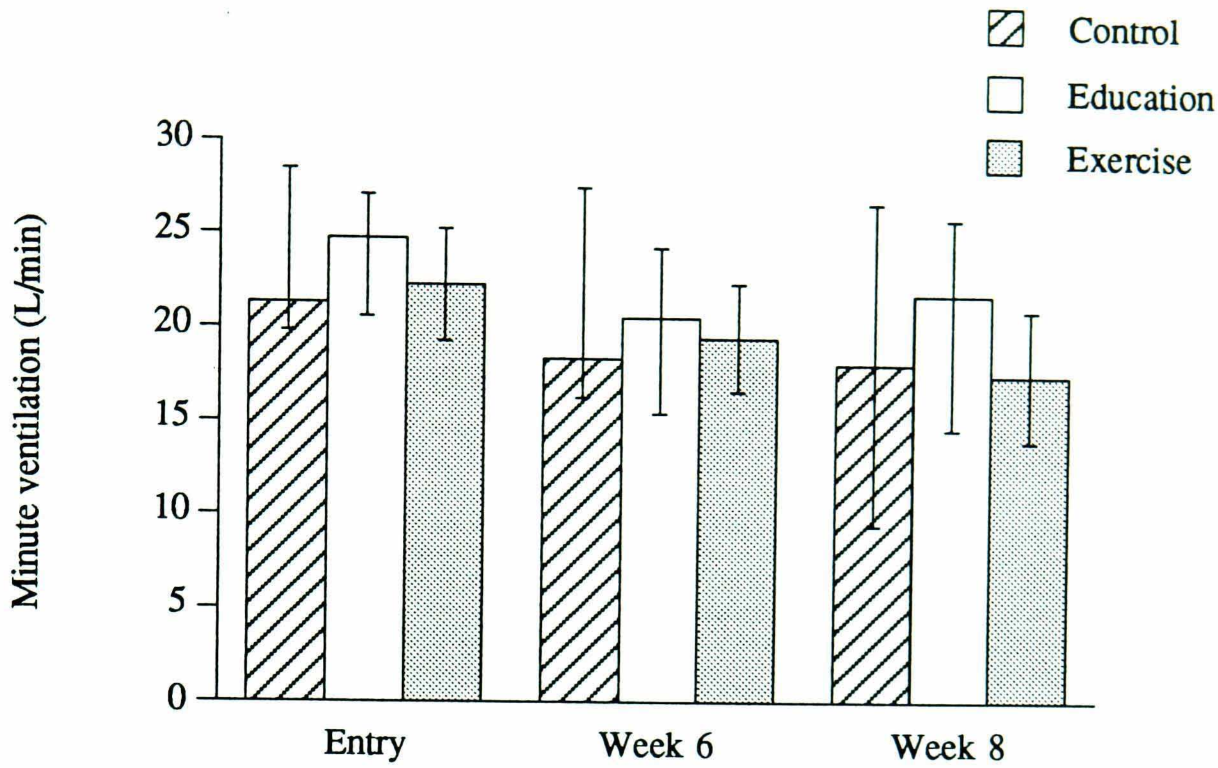


Table 5.29 Changes in VE at treadmill stage 03 expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	-10.1%	-27.1 to 13.7	-13.9%	-38.5 to 30.9
Education	-14.4%	-24.9 to 4.3	-16.9%	-36.1 to 1.8
Exercise	-10.6%	-29.1 to 10.2	-24.6%	-38.3 to -4.3

A negative value indicates a decrease compared to entry.

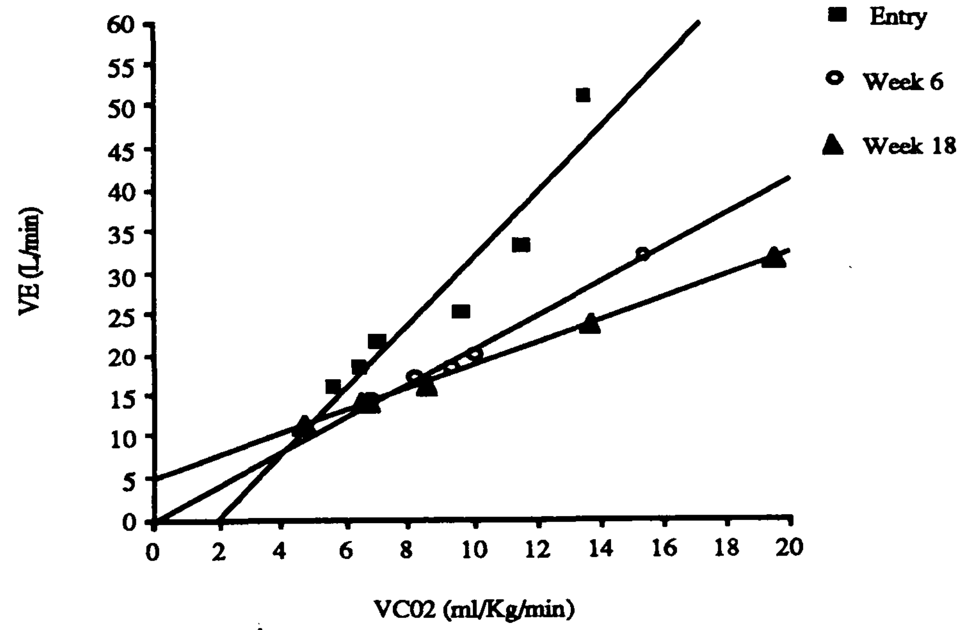
Table 5.30 Differences between the group medians for changes in VE at treadmill stage 03

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-4.6%	-19.5 to 21.6	7.9%	-14.3 to 25.7
Exercise - Control	0.8%	-17.2 to 26.9	13.2%	-15.4 to 32.5
Education - Control	3.3%	-19.2 to 24.7	2.4%	-17.1 to 22.8

A negative value indicates the changes in the first group were less than the second group.

(see Table 5.32). The decrease in slope continued at week 18 in the control and exercise groups, but the education group demonstrated an increase in gradient. The difference in change between the exercise and control groups was small, with larger differences between the education and other two groups.

Figure 5.21 Plot for an individual subject showing changes in VE and CO_2.



5.3.4 CHANGES IN TIME FOR EXERCISE TOLERANCE TEST

All groups demonstrated an increase in treadmill time as shown in Figure 5.23

When the percentage increase in time from entry to week 6, and entry to week 18 for each subject were compared, those in the education group showed least improvement at both time points (see Table 5.33). The

Figure 5.22 Changes in the relationship between VE (L/min) and VCO_2 production (ml/kg/min). Median and 95% CI.

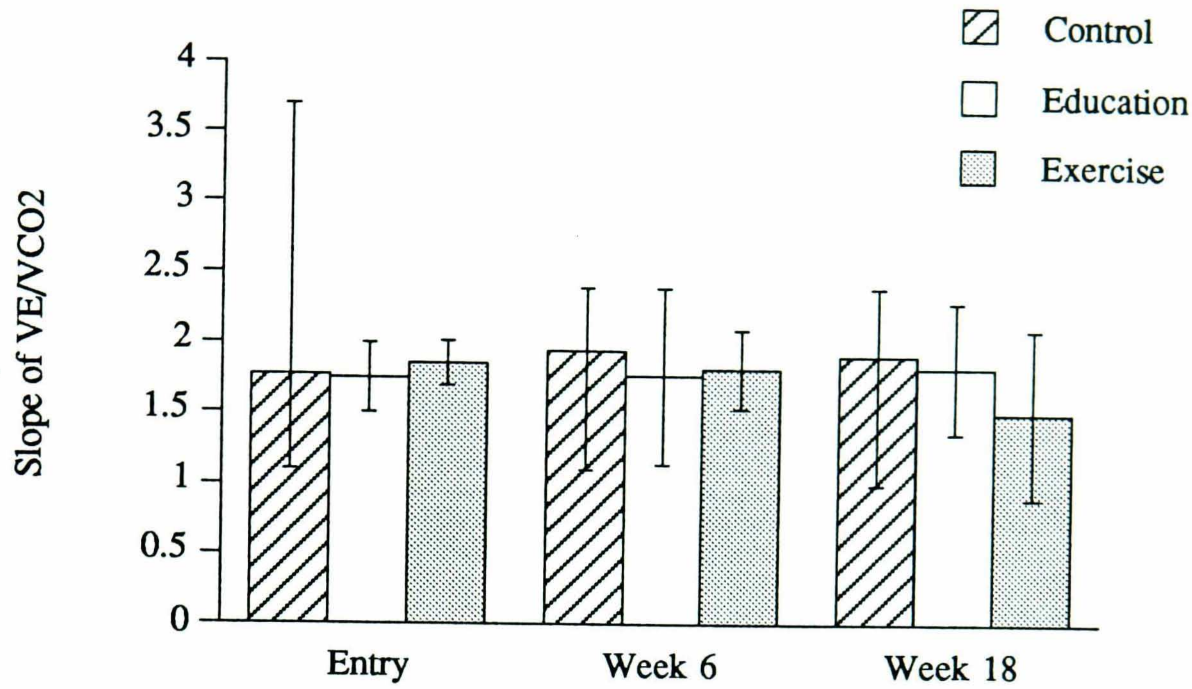


Table 5.31 Changes in slope of VE/VCO_2 expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	-6.5%	-32.3 to 63.1	-17.5%	-28.9 to 29.9
Education	-5.9%	-18.7 to 37.9	6.1%	-43.3 to 18.6
Exercise	-5.1%	-47.7 to 15.4	-16.6%	-74.9 to 15.9

A negative value indicates a decrease compared to entry.

Table 5.32 Differences between the group medians for changes in slope VE/VCO_2.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	-1.2%	-24.6 to 31.5	11.2%	-28.4 to 31.6
Exercise - Control	-2.6%	-31.5 to 41.8	-2.3%	-34.9 to 26.7
Education - Control	-2.4%	-24.7 to 43.6	-9.7%	-25.1 to 23.5

A negative value indicates the changes in the first group were less than the second group.

confidence intervals shows the exercise group was the only group at week 6 and 18 where the treadmill time did not decrease in some patients.

At week 6 the exercise and control groups showed similar increases, but despite the smaller increase in the education group, the differences between the medians were similar for all groups (see Table 5.34).

At week 18 the increase in treadmill time compared to entry was less than at week 6 for the control and education groups. The exercise group continued to increase their exercise time, with large differences between the changes for this group and the other two groups.

The pattern of increase in time of each subject at entry, weeks 2, 4 and 6, did not identify any significant difference between the education and exercise group.

5.3.5 DISCUSSION

Changes in exercise time.

All patients showed short-term improvements in exercise tolerance, but only the exercise group showed long term increases in exercise time.

The spontaneous increase in exercise tolerance, as shown by the control group, was 14% at week 6, reducing to 8.7% above entry value at week 18. The improvements in the education group were below those of the control group. This may have been due to physiological, i.e. decrease in exercise performance, or psychological factors affecting exercise time, but the increase in ~~peak~~ oxygen consumption does not support the former.

Consideration of the confidence interval and difference between the means for the changes in time suggest that for many patients the changes for the education group may have been similar to those of the control group.

Figure 5.23 Changes in time for exercise tolerance test.
Median and 95% CI.

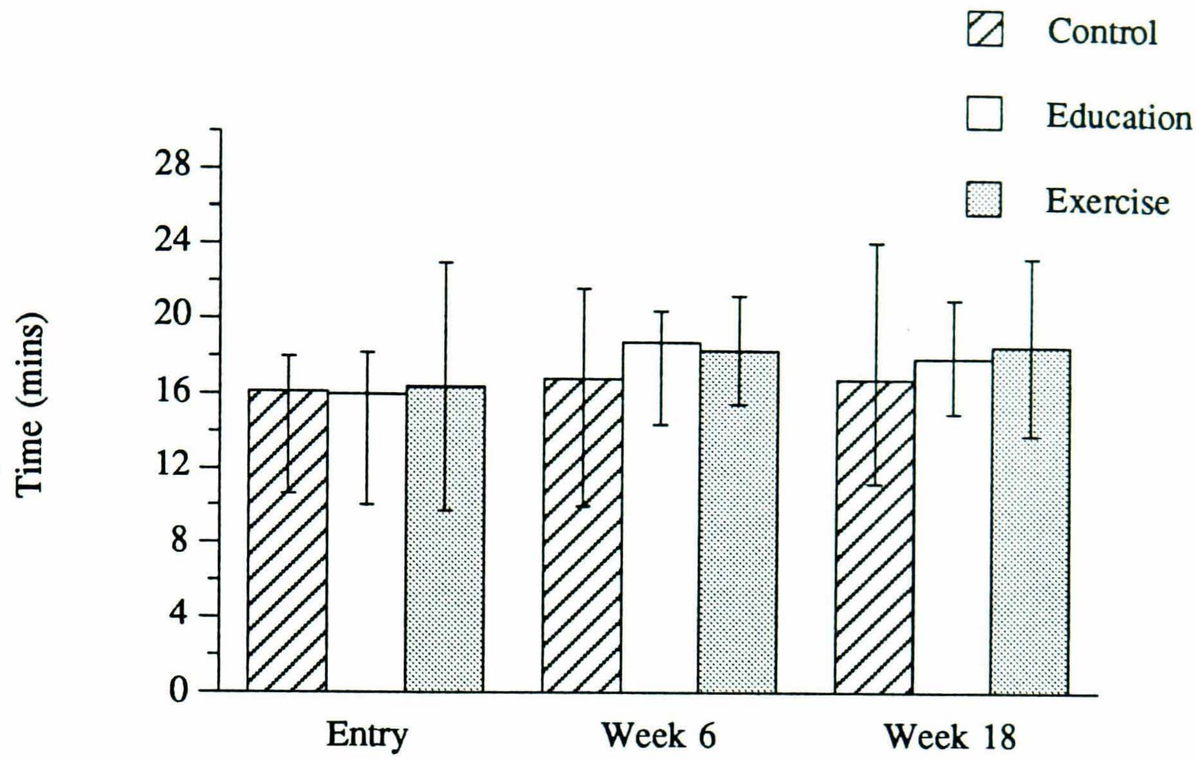


Table 5.33 Changes in treadmill time (mins) expressed as a percentage change from entry.

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Control	14.0%	-13.6 to 61.6	8.7%	-19.5 to 67.9
Education	8.9%	1.3 to 86.3	4.7%	-10.8 to 120.7
Exercise	13.1%	3.7 to 61.5	19.9%	9.4 to 376.9

A negative value indicates a decrease compared to entry.

Table 5.34 Differences between the group medians for changes in treadmill time

	Entry to Week 6		Entry to Week 18	
	Median	**95% CI**	**Median**	**95% CI**
Exercise - Education	2.6%	-27.7 to 19.2	15.0%	-3.5 to 66.5
Exercise - Control	3.4%	-16.1 to 28.9	13.4%	-0.6 to 59.7
Education - Control	-3.3%	-18.6 to 38.1	-3.0%	-14.2 to 85.9

A negative value indicates the changes in the first group were less than the second group.

Changes in oxygen uptake.

Peak oxygen uptake.

The increases in peak oxygen consumption seen in all groups throughout the study period indicated an increase in exercise performance.

The magnitude of spontaneous recovery was 5.1% at week 6 and 12.5% at week 18, although there was a lot of variation around these values. This indicates that aerobic function continues to improve to at least five months after a MI and may be linked with the continued improvement in functional activity shown by the changes in psycho-social parameters.

The increase observed in the control group at week 6 was of a similar magnitude to the increase seen between two repeated measurements of peak oxygen uptake (3.5%) described in Chapter 4.5. This suggests that the changes in value may have been largely influenced by measurement varitaion rather than changes in oxygen uptake. The magnitude of the other changes indicates they were attributable to alterations in oxygen uptake.

Participation in the rehabilitation programme bestowed greater improvements on both the exercise and education groups. In the short term the exercise training programme did not appear to provide any additional improvement in peak oxygen uptake compared to only attending the education sessions. However, at the end of the study, five months post MI, the exercise group showed a 20% improvement over the education group. The large variability in changes probably accounted for the lack of significant difference between the two groups.

The reason for the large sustained increase seen in the exercise group is not obvious from the study. The pedometer scores did not indicate they walked further than the education group at week 18, but they may have undertaken some other form of exercise on completion of the training programme which continued to improve their aerobic capacity.

The significant inverse relationship between exercise performance at entry and the magnitude of improvement is similar to that seen in healthy subjects, i.e. those with the lowest exercise capacity improved the most.

At a sub-maximal exercise load

Fox and Matthews (1981) considered a decrease in sub-maximal oxygen uptake was indicative of improved mechanical efficiency, resulting in decreased muscular activity.

Both the exercise and education group performed the same number of exercise tolerance tests and it would be anticipated that their mechanical performance on the treadmill would be similar. However, the results from the exercise test performed at 50% peak VO_2 show a significant difference between the groups at week 6, and a larger, but not significant, difference at week 18. This suggests the patients in the education group had a less efficient style of walking on the treadmill. Care was taken during the exercise tests to ensure the patients did not grip onto the equipment, thus avoiding any alteration in the muscular activity of the exercise. These differences did not occur at the fixed work load.

Changes in minute ventilation

Peak minute ventilation

The decrease in peak minute ventilation seen in all the groups indicates the increased work performance was accompanied by a decrease in respiratory stimulation.

This suggests the increase in peak oxygen consumption was due to an increase in aerobic function within the active muscles and a decrease in the production of stimulatory metabolites, i.e. lactic acid.

The absence of consistent changes in peak VE makes it difficult to determine the influence of the rehabilitation programme or exercise training on this parameter.

At a sub-maximal exercise load

The large decreases in sub-maximal VE suggests the increase in sub-maximal oxygen uptake seen in the education group was due to the wide variability in changes influencing the summary measure, rather than a reflection of the physiological response.

Relationship of VE/VCO_2

The slope of the plot of VE and VCO_2 is considered to be an index of ventilatory efficiency, with an increase in the gradient associated with increased ventilatory effort which may be due to an increase in anatomical or physiological dead space.

The similar decrease seen in all groups at week 6 suggests an improvement in ventilatory efficiency. This decrease continued in both the control and exercise groups, indicating the changes were probably related to spontaneous recovery after an MI rather than a response to exercise training.

The increase in the slope above entry level seen in the education group at week 18, may indicate a deterioration in ventilatory efficiency. These plots utilised all the data points from a symptom-limited exercise tolerance test and it is unlikely the increase in slope was due to hyperventilation. If the latter had occurred it would have been most apparent at the early stages of the treadmill protocol where psychological stimuli have more scope to influence the activity of the respiratory system. Towards the stages of peak exercise the physiological demands of the exercise would dominant and changes in the respiratory system would be harnessed to maintenance of alveolar ventilation. Inspection of the line of best fit for the plots did not suggest hyperventilation had occurred during the exercise test.

It is not possible to determine the causes of the changes in slope from this study.

Changes at the fixed work load

The results from the fixed work load suggest the response of the control group was different from the other groups at both week 6 and 18.

The control group showed an increase in oxygen consumption at week 6, indicating an increase in muscle activity, but the minute ventilation decreased as in the other groups. The increase in oxygen demand may partly explain the increase in cardiac index, but the decrease in VE suggests the increased oxygen was supplied by increased extraction from the blood.

At week 18 oxygen consumption decreased in the control group, whilst that in the education and exercise groups remained unchanged from entry. The cardiac index showed a large increase, but the VE continued to fall, suggesting the increased blood flow was directed to non-active tissue.

The respiratory changes seen in the control group at this stage lend further support to the theory that the cardiovascular system was struggling to respond to the demand of the exercise.

The reproducibility of measurements of cardiac index and oxygen uptake has not been determined at sub-maximal work loads. The changes observed in these two outcome measures were generally less than those for peak exercise levels and may have been influenced more by variation in repeated measurements than those at peak exercise.

CHAPTER 6

DISCUSSION

The main beneficiaries of the early rehabilitation programme were the patients who underwent the supervised exercise programme in addition to attending the education component.

Significant improvements in psycho-social measures were seen in this group of patients. The patients who only attended the education programme did not show any significant differences in these measurements compared to the control group, although the improvements were generally larger than the control group.

Comparison of the results of this rehabilitation study with other studies is complicated by the variety in organisation of the programmes, recruitment of patients and choice of outcome measures.

Stern has shown exercise training decreases anxiety in the short-term, but the difference diminishes with time (Stern 1984; Stern and Cleary 1981; Stern et al. 1983). Using subscales of the Minnesota Multiphasic Personality Inventory they found anxiety decreased after six weeks of low intensity exercise training and although their sample included patients ranging from 2 to 36 months after infarction, the latter was not found to influence their response. In the present study the difference in anxiety between groups was still apparent at week 18 which corresponds to approximately five months post MI. Because the exercise group also attended the education sessions it is not possible to attribute the decrease in anxiety directly to the effect of exercise training. However, the decrease in anxiety was similar for both the education and control group at week 6, suggesting the education programme had not influenced anxiety levels in the short term. This decrease in anxiety after training contrasts with the lack of difference between similar intervention and control groups after six weeks of exercise training found by the P. RE. Cor group (1991). Unfortunately it is difficult to determine precise information from this paper concerning the methodology or results of the study.

Other studies (Blodgett and Pekarik 1987; Cassem and Hackett 1973; Kavanagh et al. 1977; Ladwig et al. 1994) noted widespread and prolonged depression amongst post MI patients. This was not a feature of this study, but it may reflect a difference in identification of clinical depression. The HAD scale associates clinical depression with scores in excess of 11: none of the patients in this study reached this level.

Most studies include an assessment of return to previous activity levels or quality of life after a MI. Sivarajan et al (1982) and Erdman and Duivenvoorden (1983) both used questionnaires to determine changes in activity and found an increase in activity after completing an exercise programme. The questionnaire used by Sivarajan et al. (1982) was the Activity Questionnaire, which was investigated for use in the present study but rejected on the grounds of difficulty in completing the detail required by the questions. The authors did not report any problems in using the questionnaire in their study.

In a study similar in design to the present one, Gulanick (1991) found that all the patients, irrespective of study group, had returned to their pre-MI level of activity nine weeks after their event. This was determined by a questionnaire which was developed for the study, but no information was given concerning its validity or reliability. Additionally all patients had participated in a formal in-patient rehabilitation programme prior to being randomised to the study groups.

In this study the large increase in ambulatory activity shown by the exercise group during the six weeks of exercise training lessened once the period of supervised exercise was completed. This suggests patients need some form of extrinsic motivation and support to maintain an increase in activity level. This is often the reason cited for prolonged training programmes, but similar support for low-risk patients can be obtained from non-hospital based groups.

The confounding influence of allocation to a study group on patients behaviour has been observed by some workers. DeBusk et al. (1985) and Ewart et al. (1983) found activity increased after patients had only performed an exercise tolerance test, probably due to an increased confidence in their ability to exercise. Kolman et al. (1984) found randomisation to an active group improved psycho-social functioning, whilst both Bethell and Mullee (1990) and Sivarajan et al (1982) noted an early increase in physical activity by the control group, probably in response to an increased awareness of the risks of inactivity. This highlights the necessity of maintaining only minimal contact with a control group. During the active period in this study the patients in the control group only performed two exercise tolerance tests compared to the four of the two active groups. However, the exercise test at entry may have increased the patients confidence and explain the lack of difference between psycho-social parameters in the control and education groups in the early stages of recovery.

Additionally, the patients who volunteered to participate in the study were aware they may be allocated to an exercise group. Consequently the sample was a group of motivated patients who maybe atypical of the general population of MI patients. This may also have influenced the lack of significant difference between the control and education group.

The only area where the difference between groups was apparent at week 6 was the increase in ambulatory activity. Significant improvements in anxiety and rehabilitation status did not occur until week 18, but these changes were built upon the differences seen at week 6. This highlights the need for follow-up assessments.

The significant differences between groups for ambulatory activity and rehabilitation status were not seen in the results of the formal exercise tolerance test. This indicates that whilst the latter provides information concerning physiological changes and the potential of the patient, it does not reflect how these changes affect the patients life. To obtain this information, other more directly relevant outcome measures need to be adopted.

The information derived from the mechanical pedometers is limited to the quantity of walking: they do not provide information concerning the intensity of the activity. Similarly they cannot provide information relating to activity of the upper body when sitting or standing.

The use of questionnaires is hindered by the lack of an appropriate, established questionnaire. The modified ERSS appeared to be limited in its ability to detect changes in rehabilitation status and a suitable questionnaire still needs to be developed. This would need to accommodate patients who deny any restriction on their activities after a MI.

The paucity of significant differences between the three groups for changes in physiological parameters from entry to week 6, and entry to week 18, suggests cardiac rehabilitation did not bestow any benefit to low-risk patients recovering from an uncomplicated MI. However, inspection of the differences between summary measures of the groups generally indicates a greater improvement in physiological measurements after completion of the training programme. The reason for many of the changes not attaining significance probably lies in the variation of the responses, which are demonstrated by the wide confidence intervals.

The main physiological benefits of the training programme were an increase in peak oxygen consumption, decrease in sub-maximal heart rate and increase in exercise time.

This suggests a predominantly peripheral response to training with the increase in exercise performance due to improved aerobic metabolism in the trained muscles. Evidence of increased arterio-venous oxygen extraction in the active muscles would have been expected to accompany these changes, but this was not observed from the measurements of limb blood flow.

The latter may have been influenced by the large variability in the measurements of blood flow to the lower leg after sub-maximal exercise. This technique is very susceptible to measurement error and the observed changes in blood flow over time were within the range of variation for repeated measures. Attempts were made to minimise the influence of operator error but it is difficult to position the limb and strain gauge in the same position on repeated visits. Using this method, large changes in blood flow would have to be present in order to distinguish them from the variation in repeated measurements.

A decrease in sub-maximal cardiac index, another indicator of increased arterio-venous oxygen extraction, did not accompany the decrease in sub-maximal heart rate.

The large increases in peak cardiac index seen after training were similar to those of the control group, indicating they were due to spontaneous recovery rather than a central training response. It also demonstrates improvement in cardiac function is still occurring five months post MI in patients who have received thrombolysis and are taking beta-blockade drugs. The control group also showed similar increases in peak oxygen consumption at this time compared to the education group. This study demonstrates that the present cohort of patients recovering from an MI can expect to experience improvements in cardiac function for at least the first five months of recovery with the potential for concomitant improvement in activity level. This period of continued recovery has implications for future studies and management of these patients.

The presence of a decrease in sub-maximal heart rate and increase in peak oxygen consumption, without evidence of improved oxygen extraction or decrease in sub-maximal cardiac index, are indicators of an increase in stroke volume. Savin et al. (1981) found both peripheral and central changes in untrained patients during the early stages of recovery from an uncomplicated MI. Eleven weeks after their MI the patients demonstrated large increases in peak oxygen uptake, and increases in heart rate and peak oxygen pulse. The latter was considered to reflect an increase in stroke volume. Peripheral adaptation was suggested by decreases in sub-maximal heart rate and respiratory exchange ratio.

Other studies have indicated peripheral adaptation is the main response to exercise training and central changes only occur with high intensity, prolonged programmes lasting longer than six months (Clausen 1976; Ehsani 1987; Hagberg 1991). Unfortunately most of these studies do not provide information on the medical management of the patients, but from their date of publication, it can be assumed that most of the patients probably did not receive thrombolytic therapy. This may explain the lack of central changes due to increased myocardial damage.

Training appeared to increase the volume of circulating blood at sub-maximal loads, as shown by the increase in peak and mean blood flow in the lower leg and the increase in mean blood flow in the inactive forearm muscles. Sub-maximal cardiac index was also increased, presumably to maintain an adequate arterial blood pressure. Using venous occlusion plethysmography Silber et al. (1991) found similar results after maximal exercise with a small number of healthy subjects. They suggested the most plausible explanation for the increase in forearm blood flow after lower limb training was that training increased the release of endothelium-derived relaxing factor, causing a reduction in systemic peripheral resistance.

In this study training did not have any additional effect in improving ventilatory efficiency beyond that of spontaneous change.

No adverse events occurred during the training programme and the evidence from the Exercise training in Anterior Myocardial Infarction (EAMI) study (Giannuzzi et al. 1993) indicated deterioration in left ventricular function and ventricular dilatation were independent of the activity levels of the patients.

Many of the physiological changes seen in the education-only group were similar to those of the control group. Areas where the improvement was above that of spontaneous recovery were peak oxygen consumption and reduced heart rate at sub-maximal work loads at week 6, suggesting a greater improvement in aerobic function. As these patients did not participate in the exercise component of the rehabilitation programme, any training response would have been the result of an increase in unsupervised activity. The scores for ambulatory activity were slightly higher than the control group at week 6, and similar at week 18. However, the mechanical pedometers used in this study did not provide information concerning the intensity of the activity or any form of exercise where it was impracticable to wear them, i.e. swimming. Participation in alternative activities or brisk walking would not have been identified by the pedometers but may have provided a training stimulus.

PART B

THE EFFECTS OF EXERCISE TRAINING IN PATIENTS WITH CHRONIC HEART FAILURE

CHAPTER 7

REVIEW OF THE LITERATURE

7.1 OVERVIEW

The activity levels of patients with chronic heart failure are restricted by fatigue and breathlessness. The cause of the reduced exercise tolerance is not fully understood and has been variously attributed to inadequate cardiac output; limited vasodilator reserve; reduced skeletal muscle blood flow; changes in skeletal muscle histology, biochemistry and metabolism and reduced endurance of the respiratory muscles (Chua et al 1995; Drexler et al 1992; Mancini et al 1992; Minotti et al 1992; Poole-Wilson et al 1992; Sullivan and Cobb 1992; Wasserman 1991; Wiener et al 1986; Wilson et al 1993).

Initially the impaired left ventricular pump is compensated by tachycardia and increases in systemic vascular resistance and left ventricular filling pressure. These mechanisms attempt to increase cardiac output and maintain arterial blood pressure, with blood being diverted from regions of non-vital tissue, i.e. skeletal muscles, to vital organs (Jondeau et al. 1992; Mancini et al. 1992; Sinoway 1988; Wilson et al. 1984; Uren and Lipkin 1992). As the disease progresses the compensatory mechanisms become inadequate and the skeletal muscles are poorly perfused at rest and during exercise, with alterations in skeletal muscle metabolism and increased dyspnoea on exertion limiting exercise capacity.

Traditionally the increase in fatigue and breathless experienced by these patients during exertion has resulted in them being advised to rest and follow a sedentary lifestyle. This precipitated further decreases in their exercise tolerance with a concomitant effect on their quality of life.

7.2 EXERCISE TRAINING PROGRAMMES

One of the more recent advances in cardiac rehabilitation has been the inclusion of patients with chronic heart failure into exercise programmes. Until recent years these patients have been considered a high-risk group for exercise training programmes and have generally been excluded from joining them. This attitude has gradually changed as more experience has been gained with low and medium risk patients. As one of the factors limiting exercise tolerance is thought to be the premature onset of anaerobic metabolism, a regime of exercise training may delay this via peripheral adaptive mechanisms within the exercising muscles.

Table 7.1 summarises exercise programmes that have included subjects with chronic heart failure. There are many differences between the methodologies of the studies which hinders comparisons of the results.

Five of the studies did not include a control group/period (Arvan 1988; Conn et al 1982; Lee et al 1979; Squires et al 1982; Sullivan et al 1988) and those of Conn et al. and Squires et al. were also performed retrospectively.

The early studies based their entry criteria on impaired resting ejection fraction whilst those performed more recently adopted the New York Heart Association (NYHA) classification for chronic heart failure. It is difficult to relate the two methods to each other as decreased ejection fraction does not demonstrate a relationship with either the severity of symptoms or exercise performance.

Many of the programmes included a mixture of supervised and home exercise, the exception being Coats et al. (1990) where the exercise programme was performed at home. The latter found a relationship

Table 7.1. Comparison of different exercise programmes which include subjects with chronic heart failure.

		Exercise programme		
Study	**Subjects**	**Intensity**	**Frequency**	**Duration**
Lee et al. (1979)	n = 18 EF < 40% NYHA class I-IV	70 - 80% peak heart rate	For first 6 - 8 weeks 2-5 times a week; then weekly.	12-42 months. Mean = 18.5 months
Conn et al. (1982)	n = 10 EF < 27%	First month heart rate < 100 beats/ min then 70 - 80% peak heart rate.	3 - 5 times / week.	4 - 37 months. Mean =12 months.
Squires et al. (1987)	n = 20 EF < 25%	50 - 60% aerobic capacity.	4 - 6 times / week.	8 weeks.
Hoffman et al. (1987)	n = 41 Dilated left heart	70 - 85 % peak heart rate	3 times / week	4 months
Arvan (1988)	n = 65 NYHA I-IV	50-75% peak oxygen uptake week 1-2; 75-85% afterwards	3 times / week	12 weeks
Sullivan et al. (1988)	n = 12 NYHA class I-III	75% peak oxygen uptake.	3 - 5 times / week	4 - 6 months
Coats et al. (1992)	n = 17 NYHA class II-III	60- 80% peak heart rate	5 times/week	8 weeks.
Koch et al. (1992)	n = 12 NYHA class II-III	Muscle strength training	3 times/week	90 days
Hambrecht et al. (1995)	n = 22 NYHA class II-III	70% peak oxygen uptake	2 times/day	6 months

between compliance to the training programme and improvement in exercise performance. This had also been reported by Sullivan et al (1988), but of the other studies only that of Lee et al (1979) commented on the patients' compliance to their home exercise programme. Failure of patients to exercise regularly at home when this forms a large part of their training programme may limit the extent of their physiological responses.

The effect of different exercise intensities has not yet been explored in the way it has for patients exercising soon after a MI. Most of the training programmes involved similar intensity and frequency of exercise and appeared to be based on regimes prescribed for healthy subjects. There were wide variations in the duration of the training period which may be reflected in the differences in results. However, there did not appear to be any consistency between the duration and response to training, either in the magnitude or type of change, but this assumes high compliance with the exercise programme.

The outcome measures adopted in the studies were predominantly concerned with the physiological responses to exercise training. Generally, the patient's exercise performance improved and was found to be unrelated to the severity of their ventricular impairment.

The main responses were those associated with peripheral adaptation (see Chapter 2.2). These included increases in peak oxygen capacity (Coats et al 1992; Hoffman et al 1987; Sullivan et al 1988); increased arterio-venous oxygen difference (Sullivan et al 1988); decreased sub-maximal arterial and venous lactate levels (Sullivan et al 1989); decreased systemic vascular resistance (Coats et al 1992) and increased blood flow (Hambrecht et al 1995; Sullivan et al 1988).

Further investigations by Adamopoulos et al. (1993) of the patients involved in the study by Coats et al (1992) found that the oxidative capacity of skeletal muscle, as measured by ADP and phosphocreatine content, improved with eight weeks of training. Coats et al. (1992) also found evidence that training enhanced vagal activity and decreased sympathetic activity, similar to that seen in healthy subjects. In addition, they found changes suggesting central adaptation may have occurred in the form of an improvement in stroke volume. This contrasts with the studies performed on healthy subjects (see Chapter 2.2) where changes in stroke volume are primarily associated with prolonged periods of exercise training. Caution has to be applied in comparing measurements of ventricular function as the results can be influenced both by the method of investigation (the studies in Table 7.1 employed echocardiography, radionuclide angiography and thermodilution catheter) and the posture of the patient.

Only the studies of Sullivan et al (1988) and Hambrecht et al (1995) included an interim assessment of exercise tolerance during the period of training. Therefore, if the patient's exercise capacity in the other studies in Table 7.1 improved during training, as time progressed the patients' would be working at relatively lower sub-maximal exercise intensities. In order to maintain the same level of intensity throughout the whole period of training the patients' need to be re-assessed and the intensity of their programme increased appropriately. This is particularly important in studies where exercise is performed for longer than a few months.

There is little information available concerning the psycho-social benefits of regular exercise in patients with chronic heart failure. Mathes (1988) highlighted the problem of reduced quality of life in these patients and stated that a small improvement in exercise performance as a result of exercise training may have a major impact on their quality of life.

The paucity of information may be partially attributable to the problems in measuring changes in this area. Where studies have attempted to address this problem they have generally used questionnaires relating to changes in symptoms and activity levels (Coats et al 1992; Hambrecht et al 1995; Squires et al 1987). The validity and reliability of these questionnaires is often not stated, and there is an absence of data concerning more objective methods of measuring changes in functional activity.

The rehabilitation programme investigated by Squires et al (1987) was the only one published which included counselling and group education sessions in addition to an exercise training programme. This aspect of rehabilitation does not appear to be a feature for this patient group, in contrast to that offered to patients recovering from a MI.

The majority of studies involving the effects of exercise training for patients with chronic heart failure have the disadvantage of being based on small sample sizes. This limits generalisation of results and no studies have reported on the influence of training on mortality.

None of the exercise studies have reported any adverse events or deterioration in ventricular function as a result of training, but Kellerman et al. (1988) suggest caution when prescribing exercise for patients who have chronotropic incompetence, abnormal blood pressure response and difficulty in increasing stroke volume even at low work loads.

CHAPTER 8

METHODS OF INVESTIGATION

8.1 SELECTION OF PATIENTS AND DESIGN OF STUDY

Selection of patients

Men aged between 40-75 years with stable mild to moderate chronic heart failure (New York Heart Association class II-III) were recruited. They had symptoms of heart failure despite at least 40 mg frusemide daily, and on stable drug treatment for at least 4 weeks prior to recruitment.

Patients were specifically excluded if they demonstrated the following clinical features ;

a) non-cardiac factors influencing exercise capacity

b) valvular dysfunction

c) myocardial infarction within the previous two months

d) dependence upon a permanent pacemaker.

Nineteen patients were considered. Of these three were found to have circulatory problems in their lower limbs, two experienced difficulty in using the equipment and five declined to participate, citing time commitment as the main reason for refusal.

Of the nine patients entering the study, six had previously participated in other studies within the exercise laboratory, and three were recruited from an out-patient clinic. One patient withdrew in the initial stage as he found the exercise test had a prolonged debilitating effect and the results of his exercise tolerance test was not used in the study.

The mean age of the eight patients was 60.6 years (54.8 to 66.4) and six had incurred at least one MI. Five patients were of NYHA class II with the remaining of class III. All patients were taking angiotensin converting-enzyme inhibitor drugs. At entry the mean peak exercising METs level was 3.8 (95% CI 3.1 to 4.5).

All patients provided informed, written consent and the study was approved by the hospital Ethics Committee.

Design of the study

In anticipation of a small sample size a crossover design was chosen to compare the effects of an 8 week training programme to a similar period of normal activity. This enabled the non-training period for each patient to act as their control stage (referred to as the control period). The order of the two stages was assigned randomly.

From the review of the literature most of the exercise programmes used the same exercise intensity as that recommended for healthy subjects.

An 8 week exercise programme similar to that described for the MI patients was implemented. This comprised cycling on a static bicycle with the patients exercising at an intensity sufficient to raise the heart rate to levels corresponding to 45-70% peak oxygen uptake, determined by a formal exercise tolerance test. The length of each exercise session was determined by the heart rate and subjective response of the patient.

The principal aim was to progressively increase the length of exercise over the 8 week period, with a maximum duration of 30 minutes, excluding the 'warm up' and 'cool down' periods. After one month of the programme the patients' repeated the exercise tolerance test and the target heart rate was adjusted if necessary to maintain the same level of intensity. Heart rate was measured manually for ten seconds and the subjects exercised without ECG monitoring unless they described or exhibited symptoms on the previous exercise tolerance test which suggested the presence of adverse arrthymia.

A period of 8 weeks was chosen as this had previously been found to have beneficial effects (Coats et al. 1990; Squires et al. 1987) and its short duration was thought to promote good compliance and reduce the likelihood of a change in drug therapy during the study. Patients were required to attend the hospital 3 times a week and were given individual supervision. They were advised on an exercise programme to perform at home on non-attendance days which was similar to the supervised programme.

If a patient missed any of their exercise sessions their programme was adjusted. This was particularly important if exercise was missed through illness.

The exercise sessions were performed at a similar time of day to that of the patient's exercise tolerance test on which the intensity of the exercise was based. This was to avoid the influence of natural and pharmacological circadian variation on the heart rate.

Seven patients completed both stages of the study, with one patient completing the exercise stage but only one month of the control stage (second stage of the crossover) due to a deterioration in condition which required a change in drug treatment. For this patient the measurements obtained prior to the exercise period were used as the control data.

The novel nature of this study made it difficult to predict the magnitude of changes that would contribute to a significant change in the patients exercise tolerance level.

Evaluation procedure

All subjects performed a symptom-limited exercise tolerance test at entry, which was repeated at monthly intervals throughout the 4 months of the study. This enabled the intensity of the training programme to be increased if necessary after the first month, and provided an opportunity to monitor the rate of any changes in response to exercise training. The parameters measured were cardiac output, heart rate, respiratory gases and minute ventilation.

Measurements of limb blood flow of the lower leg and contra-lateral forearm were performed monthly using venous occlusion plethysmography.

A self-paced walk test was performed as an informal measure of exercise capacity.

The effect of the training programme on the psycho-social functioning and ambulatory activity of the patients was assessed monthly by two questionnaires and an electronic pedometer fitted into a shoe.

The questionnaires used were the Hospital Anxiety and Depression scale and a Quality of Life questionnaire designed for use in this department with patients who have chronic heart failure (Cowley and Skene 1994).

8.2 MEASUREMENTS OF PSYCHO-SOCIAL PARAMETERS

8.2.1 SELECTION OF QUESTIONNAIRES

The selection of appropriate questionnaires to measure the level of psycho-social function in this patient group posed similar problems to those for the early rehabilitation study.

The main factor considered with this group was the variation in clinical features of patients in NYHA class II and III, and its wide ranging influence on aspects of daily activity.

To overcome the lack of a suitable questionnaire in past studies within this exercise laboratory, a questionnaire had been specifically designed for use with patients with chronic heart failure (Cowley and Skene 1994). This is self-administered and consists of 30 questions divided into 6 areas (mobility; activity; home management; social, emotional and symptoms). Each question has a choice of 7 responses which are ranked from 7 (no problem) to 1 (maximum problem). A copy of the questionnaire is shown in appendix E.

The Hospital Anxiety and Depression scale (Zigmond and Snaith 1983) was used to provide specific information on the effect of exercise on these areas (see appendix D for a copy of the questionnaire).

8.2.2 MEASUREMENT OF AMBULATORY ACTIVITY

INTRODUCTION

Pedometers are considered to be an objective measuring tool, providing information on the distance walked but they do not provide any information regarding the intensity or time duration of the activity. Thus a patient may be able to walk at a faster pace or for longer periods after treatment, but the total daily distance may remain unchanged.

It was against this background that a new method of measuring ambulatory activity, the activity monitor, was designed by the Department of Medical Physics within Queens Medical Centre.

This novel tool provides information both on the quantity and quality of the activity by measuring the number of footfalls, duration and intensity of activity for up to 7 consecutive days.

During the early rehabilitation study preliminary investigations were performed with the activity monitor to determine its appropriateness as a research tool and it replaced the pedometers in the chronic heart failure study.

Mechanism of the activity monitor

The activity monitor is housed within the under surface of a standard shoe. The sensor consists of a flexible rubber conductive membrane which is positioned along the long axis of the sole of the shoe and detects movement at the metatarsal heads. This information is transmitted to a circuit board housed within the heel section where it is stored in solid state memory. A clock frequency of 0.05 Hz synchronises the control and address circuitry, allowing each accumulated data count to be stored at a new memory location. A small battery which powers the circuitry is also housed within the heel.

Several facilities have been incorporated into the design of the monitor to maximise accuracy:

1. The initial pulse of any train of signals is not transmitted, which eliminates recording changes in posture as activity, e.g. sitting to standing.
2. A time window only allows a foot fall signal to pass to the data counters if it lies within the range of 1 per second to 1 every 3 seconds. This prevents balance and weight re-distribution movements being recorded as activity and reduces the opportunity

for the patient to deliberately 'beat the system' by performing rapid plantar flexion movements.

These, together with the design of the sensor, help to eliminate the possible detection of false data and allow a high proportion of genuine activity to be stored in memory for later analysis.

Method of use.

Only one shoe of a pair is fitted with an activity monitor. Prior to use the monitor has to be fully charged and its unique code assigned to a patient via a computer. This code enables the software to recognise the shoe and patient when the data is downloaded after wear.

For the activity monitor to function it has to be recharged daily for 6-8 hours irrespective of whether it has been worn. The patients are requested to wear the shoes for most of the day and to note when they remove them. This latter information is required by the analysis programme to distinguish between periods of inactivity and non-wear. An instruction sheet (see appendix F) and diary of wear were given to the patient when they received the shoes .

Computer analysis programme

The data stored within the shoe is analysed by connecting it to an external interface linked to a IBM PC compatible computer. The data is downloaded and stored on the computer and the memory circuits within the shoe are cleared to allow it to be re-used.

The analysis programme is written in Turbo Pascal V7.0 and its main features are;

1. Storage of patient details and data from the activity monitor.
2. Day-by-day 24 hour graphical display of activity data, with facility for viewing each 60 minute period of activity (see Figures 8.1a-b)
3. Graphical display of 'average daily activity' expressed as a percentage of the time the shoes were worn (see Figure 8.1c).
4. Total number of daily steps.
5. Numerical display of actual number of steps for each 20 second period of activity.

The classification of the levels of intensity for the 'average day' were based on the performance of healthy subjects with an age range of 23-54 years.

METHOD OF INVESTIGATION

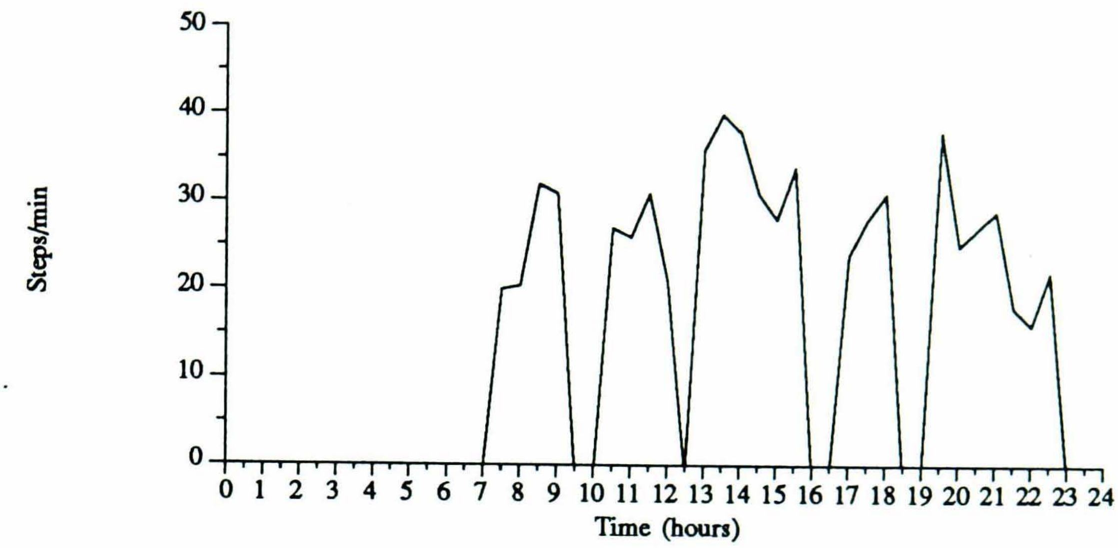
Determination of validity and reliability of the activity monitor

The validity and reliability of the activity monitor was investigated by healthy subjects performing repeated walks whilst counting the number of steps taken using a mechanical counter. The chronological time and duration of the walks were noted to determine the accuracy of the timing mechanism of the monitor.

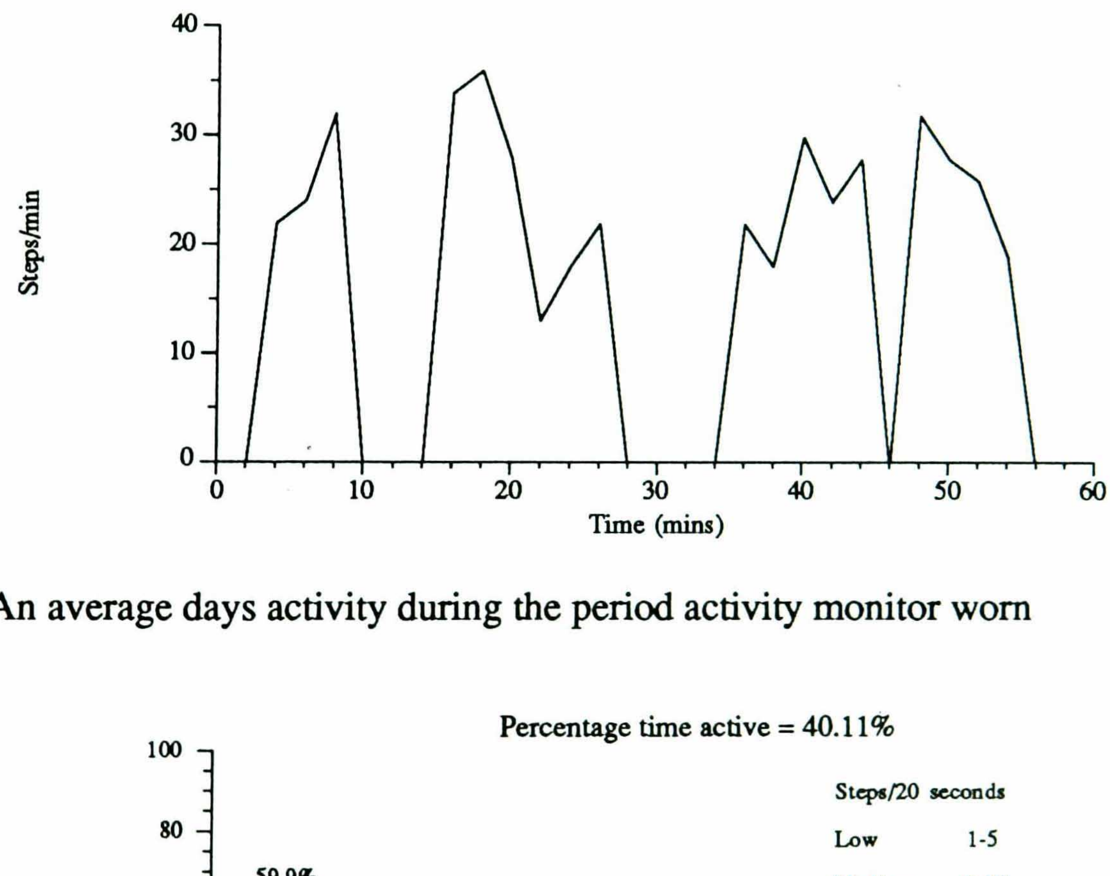
The first stage was to determine whether the speed of walking influenced the scores of the activity monitor.

Figure 8.1 Example of information recorded by the activity monitor.

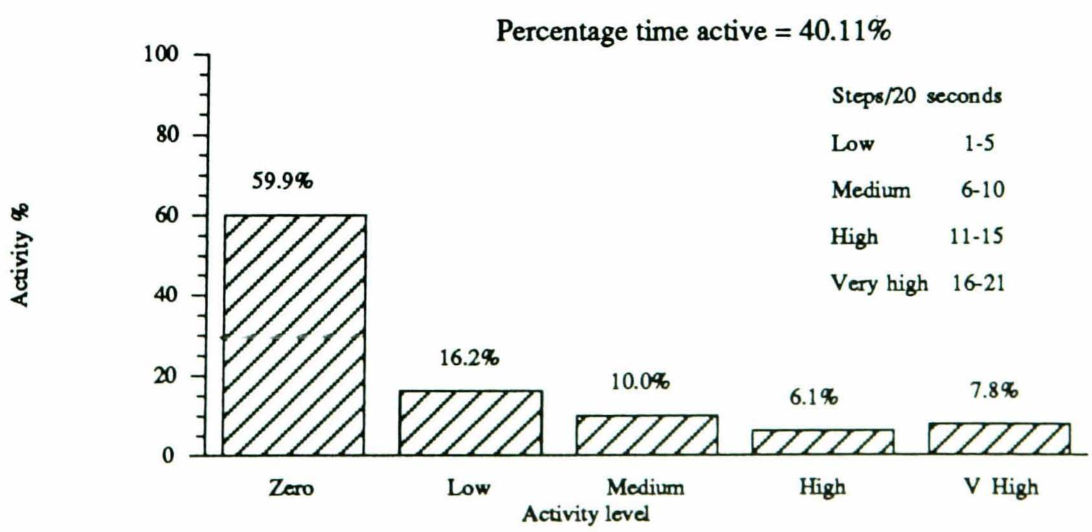
a) Activity over a 24 hour period



b) Activity for one hour



c) An average days activity during the period activity monitor worn



a) Influence of walking speed on accuracy of the monitor

Method

Two subjects performed a total of 36 walks of 10 minutes duration on a treadmill at constant speeds of between 3-7 Kph.

Results

The activity monitor scores ranged from an underscore of 2.4% to an over-score of 1.1% with a mode over-score of 0.2%. Figure 8.2 shows the scores for 26 walks from the same subject. The minute-by-minute graphic display clearly identified the different intensities of the walks and the start and stop chronological times of the walks were the same as an external clock.

Conclusion

The scores for these two subjects were not influenced by the speed of the walk and the timing mechanism appeared to be as accurate as other analogue timing devices.

b) Determination of the accuracy and reliability of the monitor.

Method

Eight healthy subjects walked for 10 minutes on a treadmill at self-selected speeds of between 3-4 Kph. They immediately repeated the walks under identical conditions, each performing a total of three walks.

Figure 8.2 Scores for activity monitor over 26 treadmill walks for one subject.

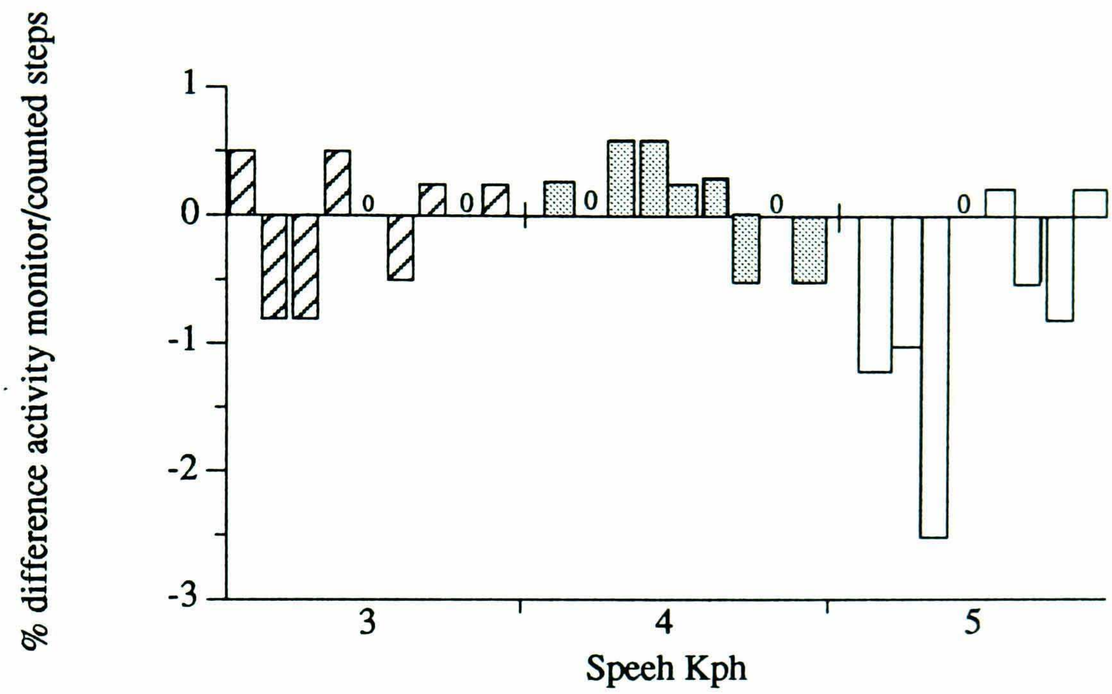
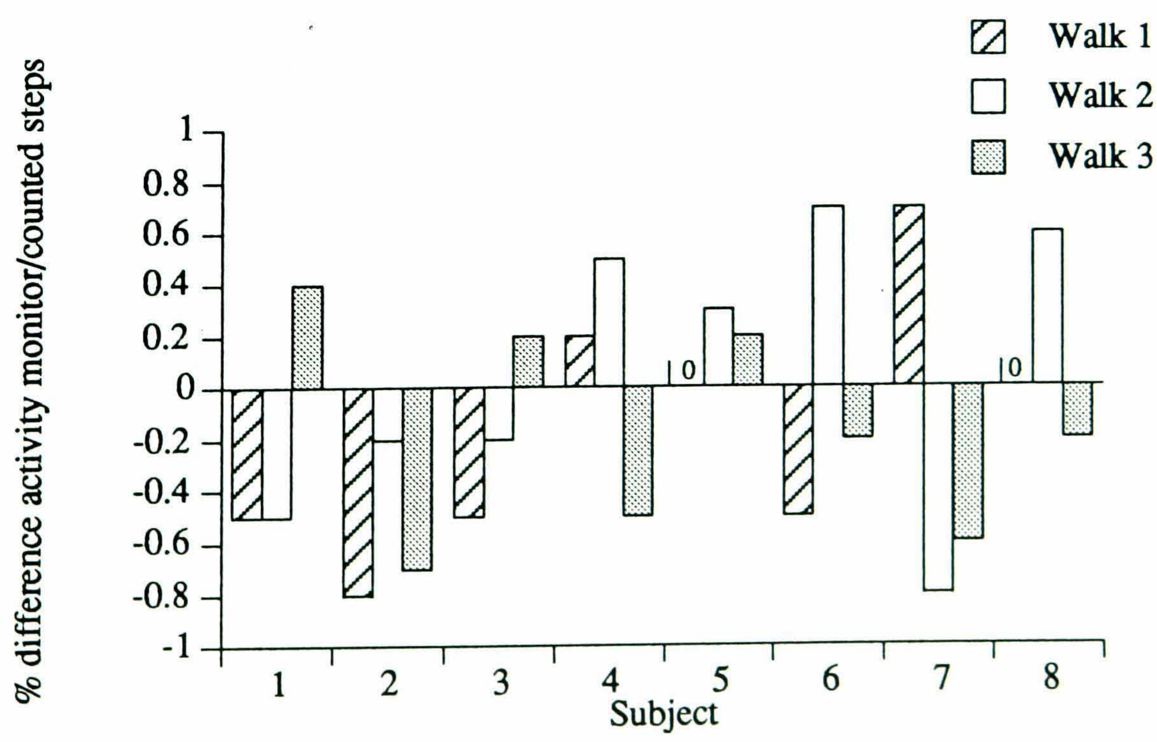


Figure 8.3 Scores for activity monitor during treadmill walks for 8 subjects



Results

The percentage difference between counted and monitor scores ranged from an under and over-score of 0.8% with a mode under-score of 0.2% (see Figure 8.3).

Conclusion

The accuracy and reliability of the activity monitor was not affected by individual subjects and the monitor appeared to be both an accurate and reliable method to measure footfalls.

DISCUSSION

Unfortunately it was not possible to assess the validity and reliability of the activity monitor when worn for normal activity as an established 'gold standard' measuring tool was not available with which to compare the results. However from the results of walking in a controlled environment it was not anticipated there would be any validity or reliability problems with the device.

From these investigations the activity monitor was considered a reliable and valid means of quantifying a subjects level of ambulatory activity. It has the advantage over mechanical pedometers in providing qualitative information on activity rather than just the quantitative data of the pedometers. Importantly, it is also more accurate and reliable than the pedometers tested for the early rehabilitation study.

8.3 MEASUREMENTS OF PHYSIOLOGICAL PARAMETERS

Measurements were performed to detect the presence of any training effects and were made during an exercise tolerance test on a treadmill following a modified Bruce protocol (see Chapter 4.3.1). The measurements included changes in central and peripheral haemodynamics, exercise capacity determined by oxygen uptake and exercise time, and changes in selected respiratory variables relating to breathlessness.

Most of the measurements were the same as those performed in the early rehabilitation study (Chapter 4), where the techniques are described in detail.

Six of the eight patients were already familiar with the measurement procedures, having participated in previous studies within the exercise laboratory. These patients underwent a re-familiarisation session before they entered the study. The remaining patients were unfamiliar with the laboratory and both underwent two practice sessions before they were considered to be able to satisfactorily perform the rebreathing technique during exercise and their exercise time did not vary by more than 5%.

8.3.1 MEASUREMENT OF CARDIAC OUTPUT

Cardiac output was measured non-invasively at rest and during exercise using the indirect Fick rebreathing method described in Chapter 4.4.2.

The reproducibility of this technique within this exercise laboratory had previously been determined by Muller (1992). He found the technique had a coefficient of repeatability of 0.86 L/min at rest using 30 patients with NYHA class II and III chronic heart failure.

8.3.2 MEASUREMENT OF LIMB BLOOD FLOW

Changes in peripheral blood flow are common in patients with chronic heart failure and these were investigated at rest and after sub-maximal exercise by venous occlusion plethysmography (see Chapter 4.4.3).

When 30 patients with NYHA class II and III chronic heart failure were investigated, Muller (1992) found a coefficient of variation of 9% at rest for the lower leg and 10.5% for the forearm, with smaller values after exercise.

8.3.3 MEASUREMENT OF RESPIRATORY PARAMETERS

Data concerning oxygen uptake, carbon dioxide excretion and minute ventilation were obtained at rest and during exercise by means of a mass spectrometer and flow meter. Their arrangement within a breathing circuit and method f sampling respiratory gases is described in Chapter 4.5.

In addition to analysing the measurements independently, the relationship between VE and VCO_2 was investigated. In patients with chronic heart failure this is considered an index to the severity of the disease and related to changes in ventilatory efficiency (Buller and Poole-Wilson 1990). Plots of VE (L/min) and VCO_2 (ml/kg/min) were drawn for each subject using all the data points from the exercise tests. The slopes of the plots were determined and compared before and after training.

Changes in ventilatory carbon dioxide equivalent (VE/VCO_2) during the exercise tests were also investigated to determine the time when it reached its lowest value. This represents the point of maximum ventilatory efficiency per unit of CO_2 production and has been shown to change after a period of exercise training (Davey et al. 1992). The times at which this occurred were compared between the control and training periods.

8.4 STATISTICAL ANALYSIS

The method of Hill and Armitage (1979) was used to detect the presence of period and carry-over effects between the two phases of the cross-over design for all parameters. None were found.

Whilst the order of the study periods were randomised at recruitment, the results of the control period are presented as the first value to maintain uniformity.

Both parametric and non-parametric tests were used to analyse the results as appropriate, and summary values are expressed as mean or median with 95% Confidence Interval.

Measurements were compared on completion of the exercise and control stages and the effect of the training programme was expressed as a percentage increase or decrease with respect to the control value. The mean or median value, and 95% Confidence Interval for this change, was determined using the method described by Gardner and Altman (1989). When the confidence interval contains a negative value i.e.-6 to 10, it denotes that in some patients the measurement decreased after training.

The two sets of results were compared either using a t-test for paired samples or a Wilcoxon matched-pairs signed-ranks test and $p<0.05$ was used as the level of significance.

When a significant difference was found the analysis was repeated between the control period and completion of the first month of training to identify when the changes occurred within the exercise programme.

Spearman rank correlation coefficients were used to determine the relationship between changes in different measurements.

CHAPTER 9

RESULTS

9.1. CHANGES IN PSYCHO-SOCIAL MEASUREMENTS

9.1.1 RESULTS

Quality of life

The change in the scores for the quality of life questionnaire are shown in Figure 9.1.

The total score for the questionnaire showed a significant increase of 11% (-4 to 16) after training, indicating an overall improvement in the patients quality of life. Whilst an improvement was seen in all the sections of the questionnaire, only that recording emotional change reached significance, with an improvement of 17% (0 to 37).

When both these changes were investigated further, a significant improvement was found in the emotional section after only one month of exercise, (7% [0 to 25]). During the same time the improvement in the total score was 4% (-4 to 12), which was not significant.
After the two month training period the patients experienced an 12% improvement (-8 to 25) in their symptoms, an increase of 10% (-12 to 13) for social function and 7% (-6 to 16) in activity.

Anxiety and depression

Figure 9.2 shows that both these levels fell after training, with a significant fall of 50% (0 to -100) in depression and a 11% reduction (-75 to 43) in anxiety.

Figure 9.1 Changes for quality of life questionnaire. Median and 95% CI. Increase in score denotes improvement. *p<0.05

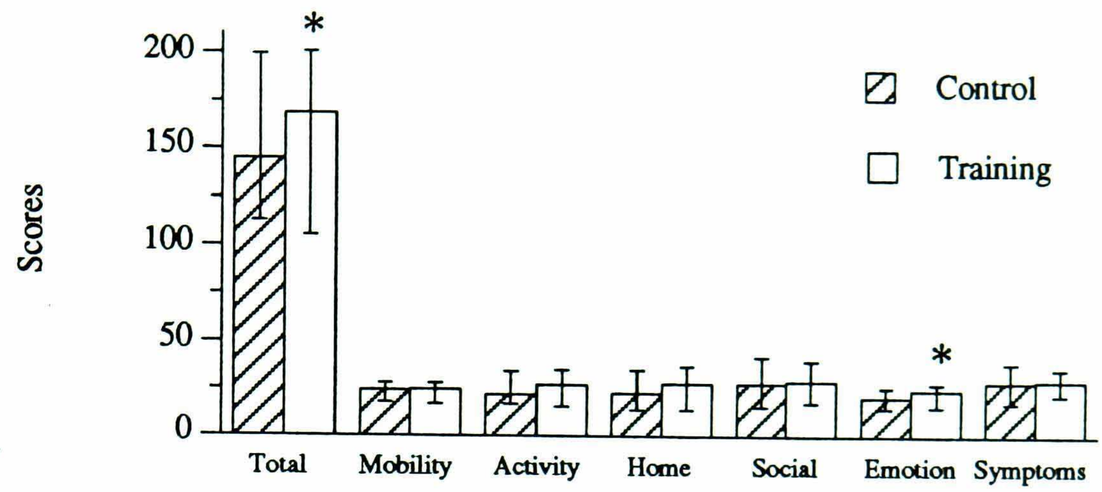


Figure 9.2 Changes in anxiety and depression. Median and 95% CI. Decrease in score denotes reduction in state. *p<0.05

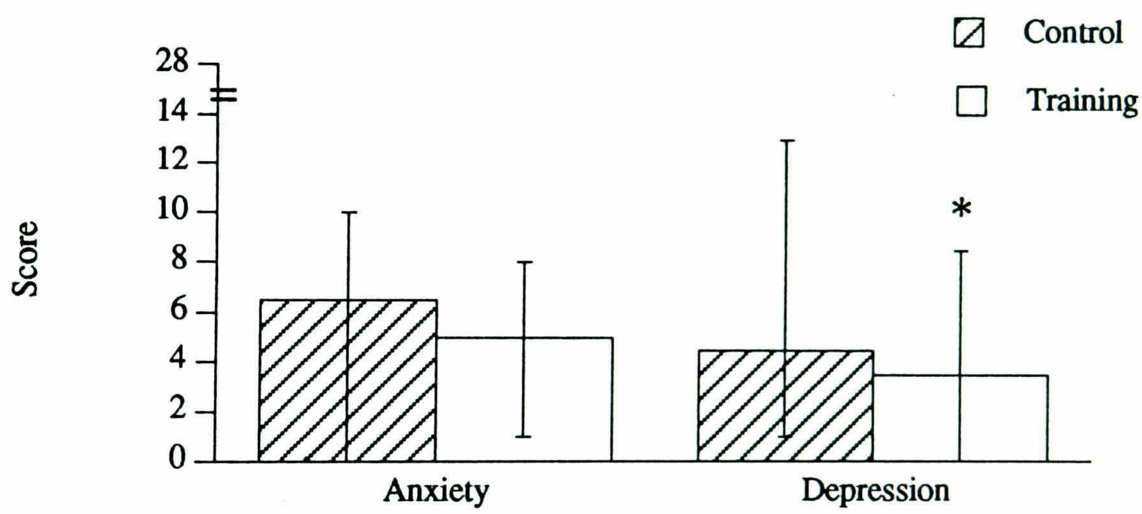
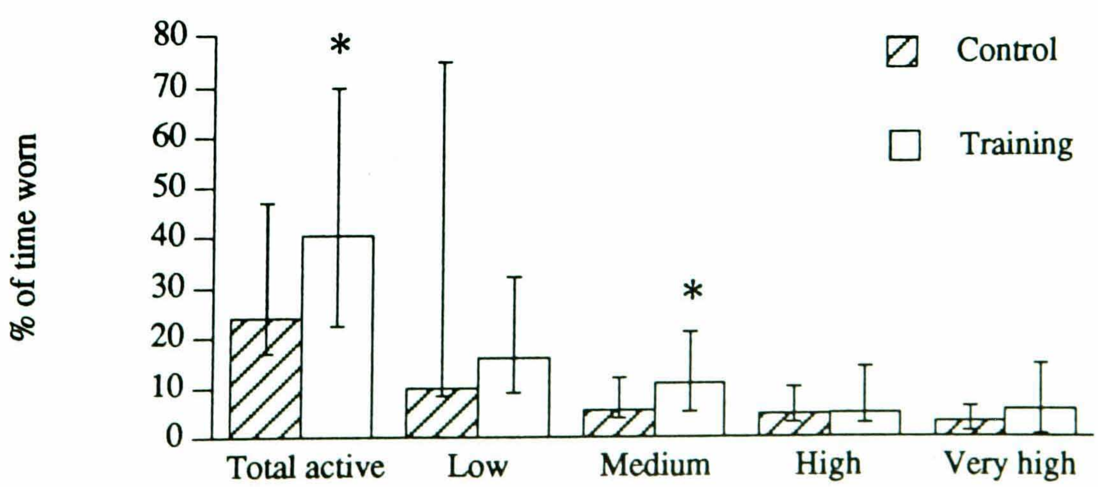


Figure 9.3 Changes in activity monitor scores. Median and 95% CI. *p<0.05



A decrease of 4% (-2000 to 100) was seen in depression after one month of exercise, but this was not significant.

A significant correlation was found between the decrease in depression and the improvement in the symptom section of the quality of life questionnaire (r_S-0.76).

Activity monitor

After the period of training the patients walked for more of the day, with an increase in the time spent at most of the different levels of activity (see Figure 9.3).

The total time of the day spent walking showed a significant increase of 63% (36 to 65) after training, accompanied by a similar increase in medium pace activity (62% [37 to 185.7]) at 18-30 steps/minute.

The largest increases in activity occurred at the ends of the range, with an increase of 252% (-7 to 524) at the low speed (3-15 steps/minute) and 120% (-84 to 213) for the very high intensity level (48-63 steps/minute). The period for the high level of intensity (33-45 steps/minute) increased by 42% (-35 to 120). None of these were significant, probably due to the wide variability of the scores.

Due to technical problems with the activity monitor (failure to operate; software faults) it was not possible to compare the changes after one month of exercise training with the control period.

The total number of daily steps were not used in the analysis as some of the patients removed the shoes for part of the day.

9.1.2 DISCUSSION

Exercise training had a marked effect on the functional status of this group of patients.

The results from the activity monitor demonstrated that all eight patients showed a large increase in the proportion of the time for which they were active after completing the training programme.

For most patients this increase was attributable to longer periods of activity at all levels of intensity, indicating the wide influence of the training programme. On completion of the exercise programme the patients increased the time spent at the very high level of intensity, which is equivalent to fast, purposeful walking, to equal the time spent at the high intensity, with the latter equating to a brisk walking pace. All patients showed an increase in medium intensity, which suggests this level may equate with the intensity of the exercise programme.

This increase in activity is important not only for its influence on the patients quality of life but also for its possible effect on the patho-physiology of the condition. An increase in general activity, especially if it is accompanied by an increase in intensity, will augment the physiological responses of formal exercise sessions and facilitate an improvement in muscle function

An interesting feature was the improvement in ambulatory activity did not correlate with the changes in the activity section of the quality of life questionnaire, which were predominately concerned with walking. This probably reflects the difference between the quantitative measurements of the activity monitor and the qualitative aspect of the questionnaire - the large improvement in physical activity measured by the monitor did not translate to a perceived decrease in dyspnoea or fatigue.

The activity monitor required a high level of compliance from the patients and some found they were unable to wear the shoes continuously for a week. Whilst this prohibited comparison of total daily steps, the computer's method of analysis was able to determine an 'average day' of activity by taking into account identified periods of non-wear. As the monitor only records walking activity it is limited by similar constraints to those of mechanical pedometers, in that activity of the upper body or situations when footwear is inappropriate are not recorded. Whilst the patients were advised not to modify their usual activity when wearing the adapted shoes it is difficult to ensure they performed a week of 'typical' activity.

To achieve a significant decrease in depression the training programme had to be performed for two months. With this group of patients a decrease in depression was not accompanied by a similar fall in anxiety, with the level of anxiety remaining higher than depression on completion of the training programme.

The moderate correlation between the improvement in symptoms and decrease in depression after training suggests these two factors are associated with each other.

The training programme significantly improved the emotional state of the patients after only one month. After two months training there was an additional improvement in their overall quality of life.

The improvements in emotional status did not correlate with either changes in anxiety or depression as measured by the HAD scale. This may have been due to the specific nature of the questions in the latter and the use of 14 questions rather than 5.

In summary, the training programme increased ambulatory activity, reduced depression and generally improved the patient's quality of life.

9.2 CHANGES IN HAEMODYNAMICS

9.2.1 CHANGES IN HEART RATE

All eight patients showed a decrease in resting heart rate after training (see Figure 9.4), with a significant mean reduction of 13.5% (3.5 to 23.0). After one month of exercise the group showed a mean decrease of 9.1% (-19.4 to 1.4), which was not significant.

The changes in peak heart rate were variable (see Figure 9.5), with a median decrease of 3.0% (-12.9 to 1.7).

The two sub-maximal work loads showed differing changes in heart rate. That at 50% peak VO_2 showed a mean increase of 6.2% (-1.4 to 13.8), whilst a decrease of 2.7% (-8.7 to 3.3) was found for the fixed work load after training (see Figures 9.6 and 9.7).

9.2.2 CHANGES IN CARDIAC INDEX

Due to the longitudinal nature of the study the measurements of cardiac output are presented as cardiac index (L/min/m^2). The values used in the analysis are the percentage increase or decrease in cardiac index from the resting value.

The resting cardiac index decreased by 2.8% (-16.9 to 11.3) after training, whilst the peak cardiac index increased in most patients (see Figure 9.8) with a significant median increase of 13.1% (1.5 to 29.3). No significant changes occurred after a month of training.

Figure 9.4 Changes in individual and mean (95% CI) resting heart rate.
*p<0.05

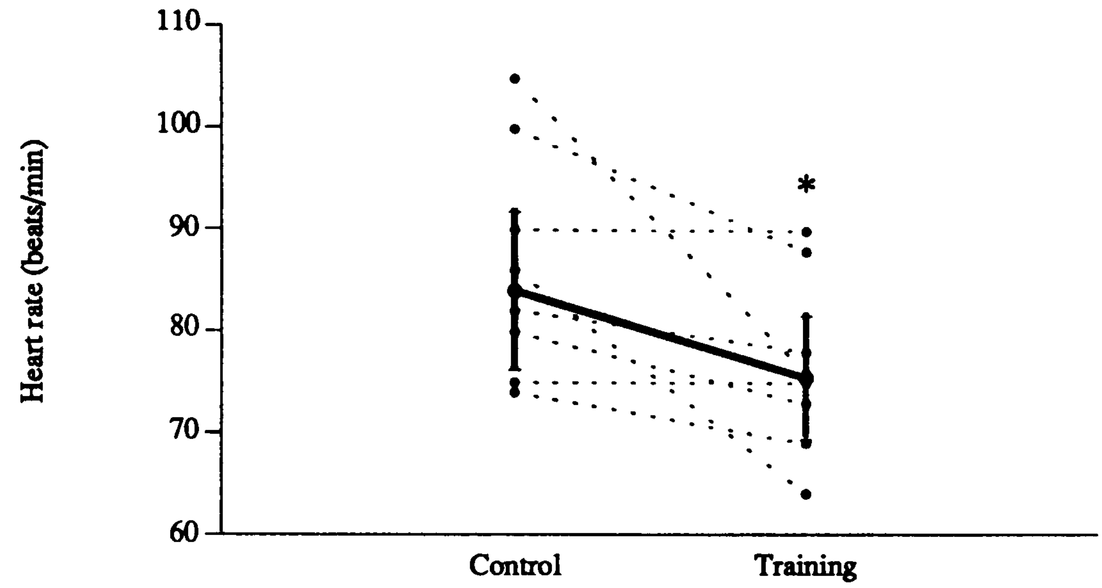


Figure 9.5 Changes in individual and median (95% CI) peak heart rate.

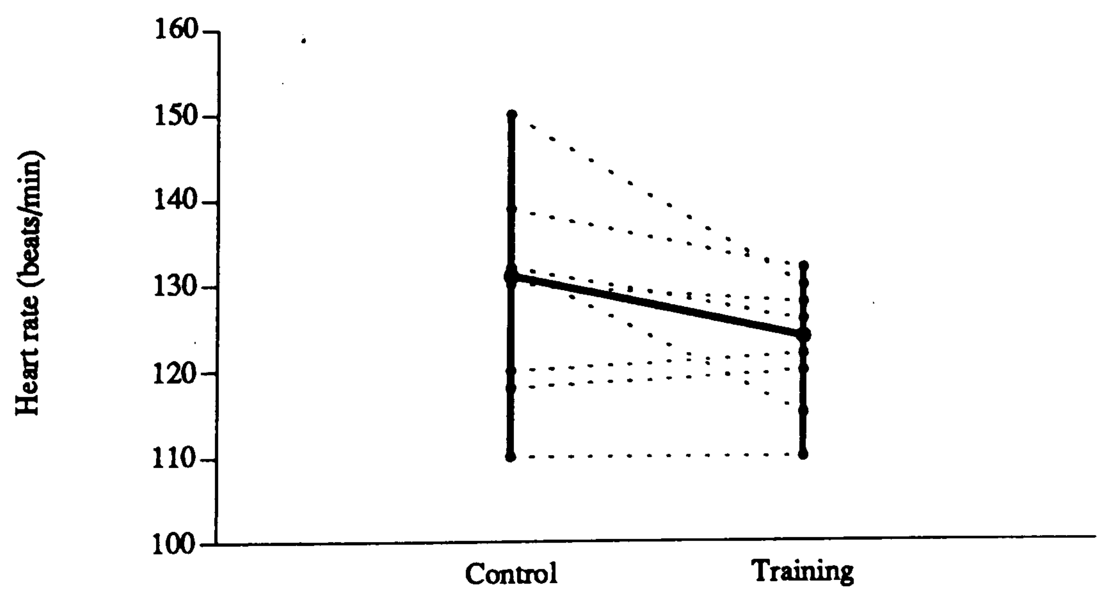


Figure 9.6 Changes in individual and mean (95% CI) heart rate at sub-maximal load equivalent to 50% peak VO_2 uptake at entry.

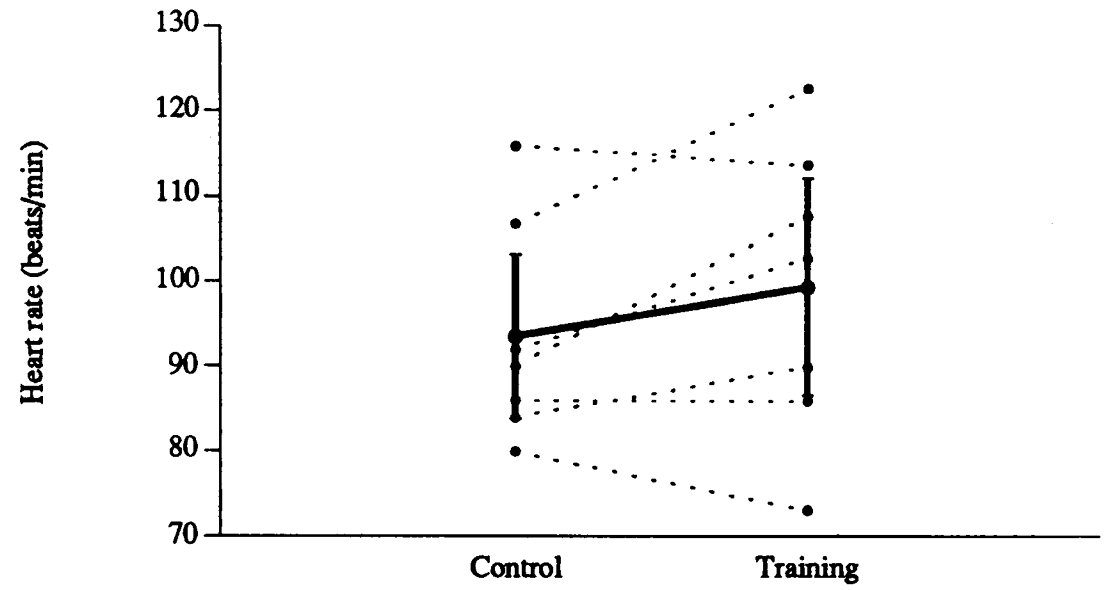
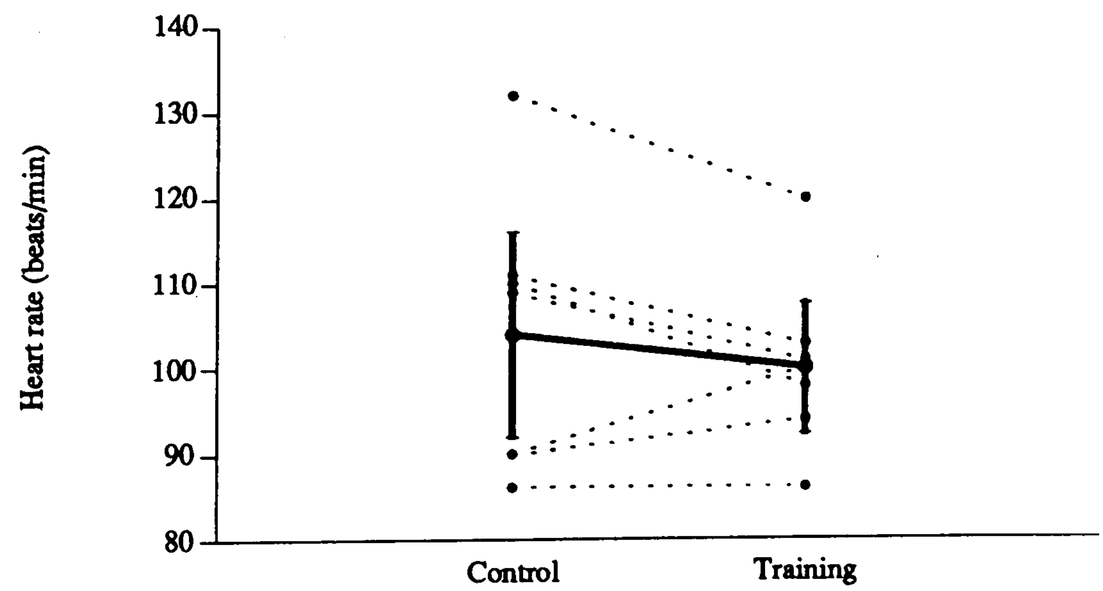


Figure 9.7 Changes in individual and mean (95% CI) heart rate at workload 03 of treadmill protocol.



The changes in cardiac index at two sub-maximal workloads were investigated. These were the work load that corresponded to 50% peak oxygen uptake at the time of entry, which was generally stage 01, and a fixed work load of stage 03.

There were variable changes in cardiac index after training at both sub-maximal loads (see Figures 9.9 and 9.10). At the 50% peak VO_2 work load there was a mean increase of 3% (-18.6 to 24.6) after training, with a larger increase of 6.1% (-14.9 to 27.2) at stage 03. None of these changes were significant.

9.2.3 DISCUSSION OF CHANGES IN CENTRAL HAEMODYNAMICS

The significant decrease in resting heart rate indicated a training response occurred in these patients after two months of exercise training. This is supported by the significant increase in peak cardiac index.

From this study it is not possible to determine the contribution of changes in stroke volume or the autonomic nervous system towards the reduction in resting heart rate. The increase in peak cardiac index and minimal change in peak heart rate suggests a change in stroke volume may have occurred.

The changes in peak cardiac output may have been under-estimated as cardiac output was only measured during alternate stages of the exercise protocol. Unless a patient terminated the test immediately after a rebreathing manoeuvre they would have achieved a higher exercise cardiac output than the last measurement. As breathlessness was the main reason for stopping the exercise test the patients would have experienced difficulty in performing a satisfactory rebreathing manoeuvre on

Figure 9.8 Changes in individual and median (95% CI) peak cardiac index. *p<0.05

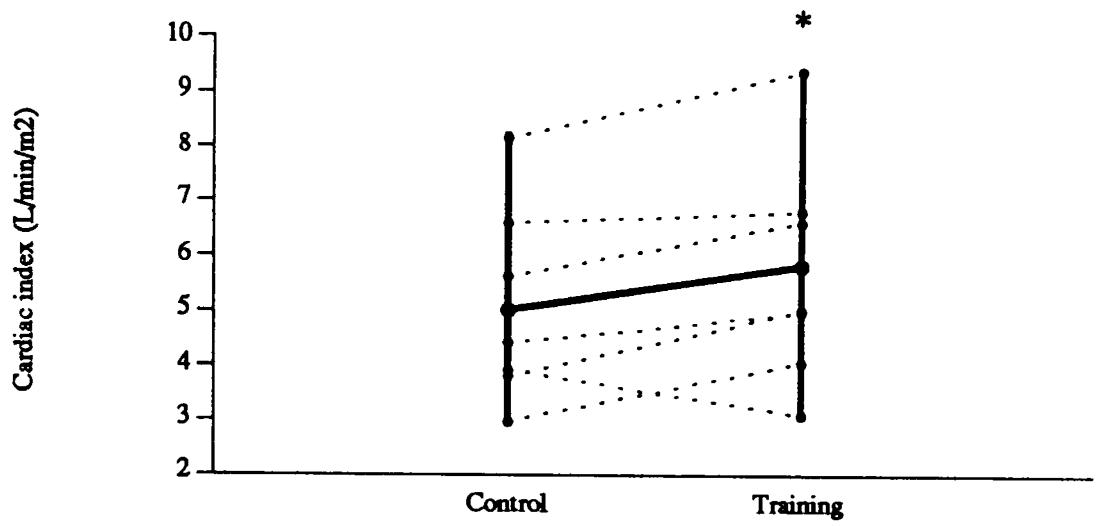


Figure 9.9 Changes in individual and mean (95% CI) cardiac index at sub-maximal load equivalent to 50% peak VO_2 uptake at entry.

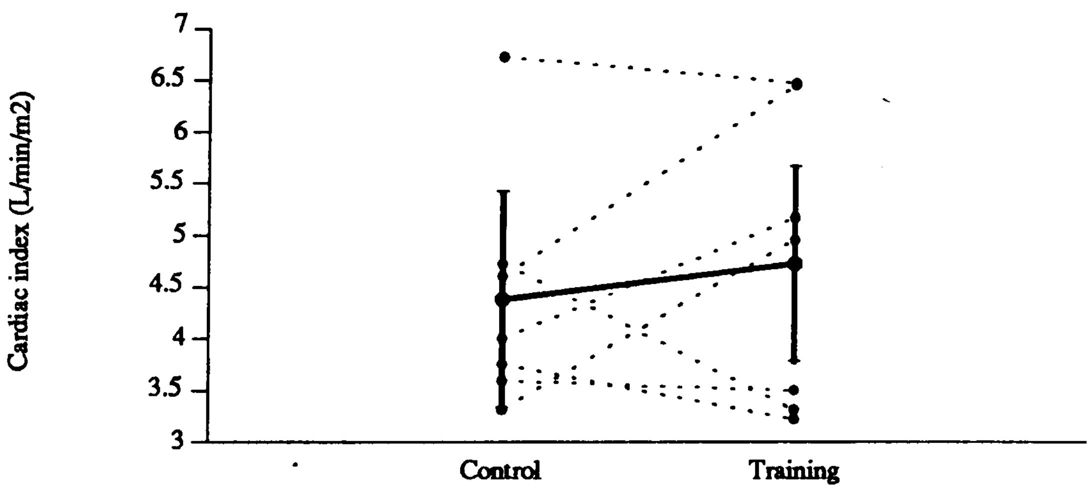
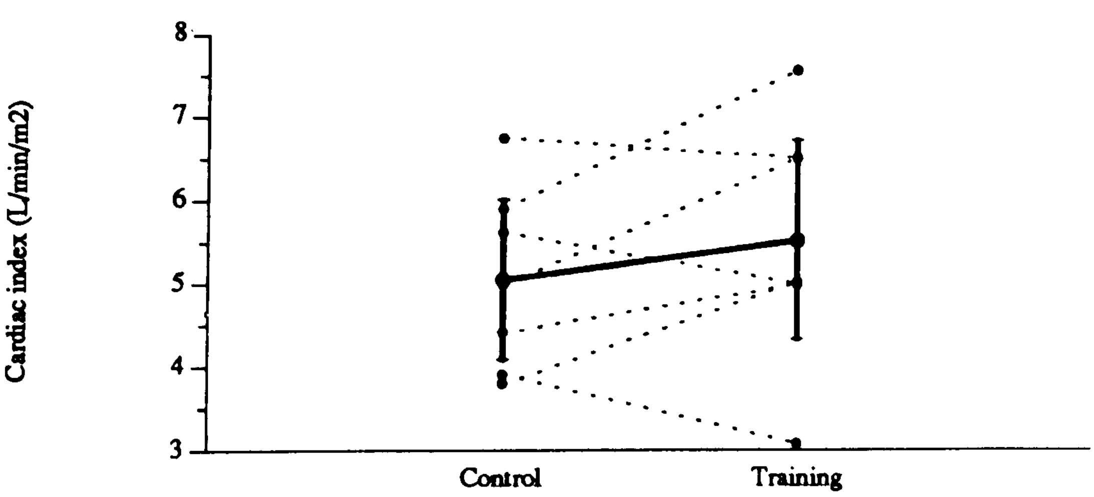


Figure 9.10 Changes in individual and mean (95% CI) cardiac index at workload 03 of treadmill protocol.



completion of the test from which determination of the cardiac output could have been made.

For most patients the work load equivalent to 50% peak VO_2 occurred at stage 01 and consequently was a lower intensity than the fixed workload at stage 03.

The changes in cardiac index at both sub-maximal loads were accompanied by wide confidence intervals and probably do not represent precise changes. This large variability in cardiac index appears to be a feature with this group of patients at sub-maximal work loads and makes interpretation of changes difficult.

The changes in sub-maximal heart rate were interesting as they appeared contrary to the different work intensities. At the generally lower intensity (50% peak VO_2) the heart rate increased after training, indicating an increase in cardiovascular stimulus, whilst it decreased at the higher 03 stage. Whilst the changes are small the confidence intervals suggest the direction of change (increase or decrease) is a reflection of the changes of the group.

9.2.4 CHANGES IN LIMB BLOOD FLOW

Resting blood flow

Figure 9.11 shows the changes between resting blood flow in the lower leg and 3 minutes after sub-maximal exercise. It indicates a small decrease in resting blood flow after training, but the median of the individual changes showed it decreased by 21.5% (-238.9 to 58.5).

Figure 9.11 Lower leg blood flow at rest and 3 minutes after sub-maximal exercise. Median and 95% CI.

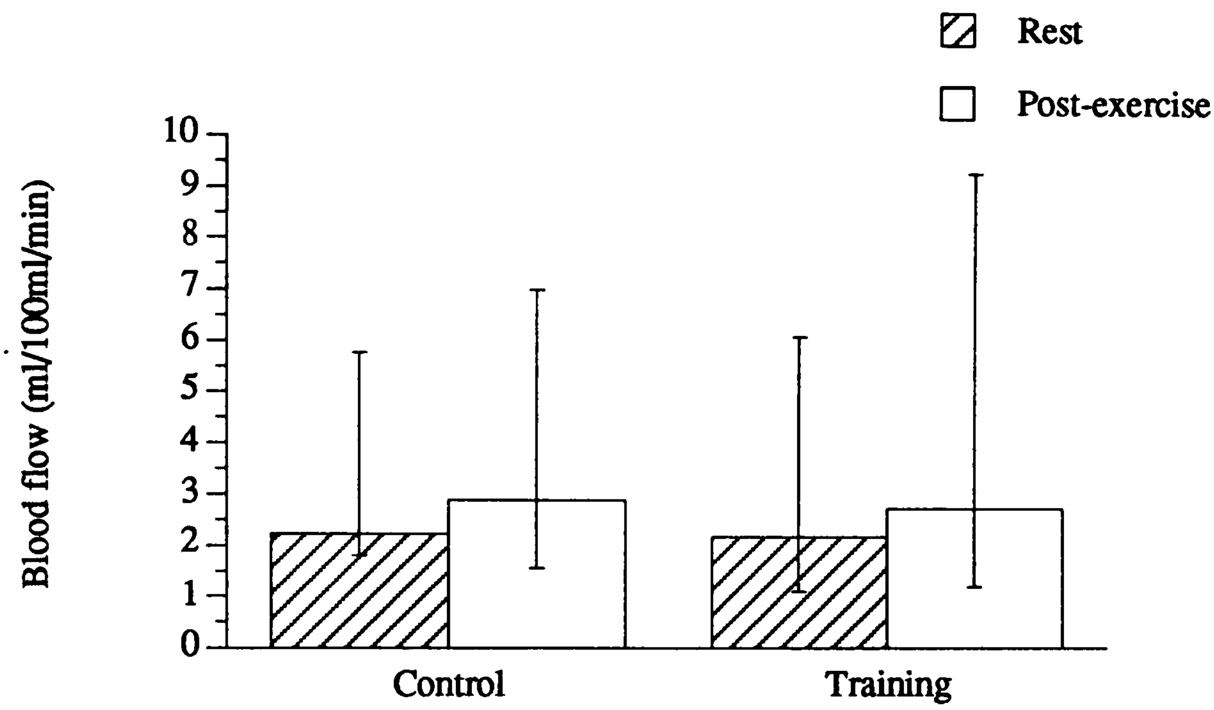
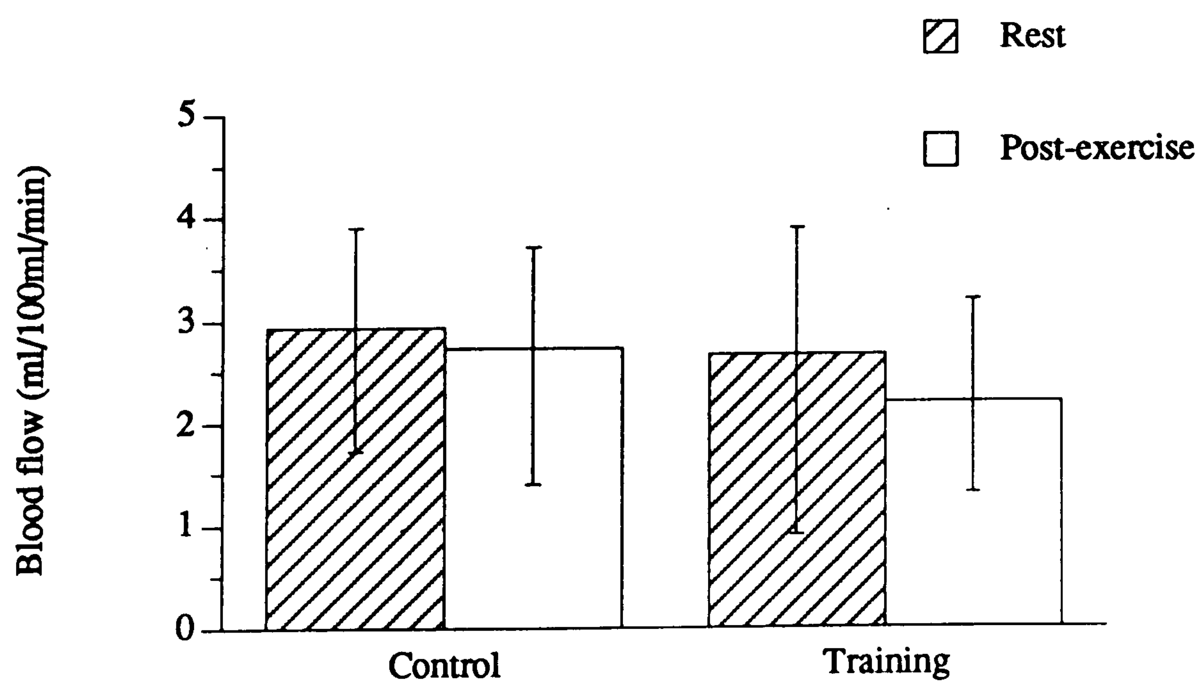


Figure 9.12 Forearm blood flow at rest and 3 minutes after sub-maximal exercise. Median and 95% CI.



The resting blood flow to the forearm also decreased after training. Again the median of the individual changes (decrease of 16.9% [-56.1 to 31.5]) was larger after training than that shown in Figure 9.12.

Post sub-maximal exercise blood flow

Figure 9.13 illustrates lower leg blood flow 3 minutes after sub-maximal exercise during the control and training periods.

Due to the large changes in individual values for resting lower leg blood flow after training, the peak increase in blood flow after sub-maximal exercise was expressed as an increase above its resting value rather than as absolute values. In the control period it increased by 19.6% (-20.5 to 55.2) above rest and by 43.1% (-12.9 to 132.3) after training (see Figure 9.11). Hence the training programme increased peak lower leg blood flow by 31.6% (-7.2 to 52.5) .

The mean lower leg blood flow increased by 12.0% (-17.5 to 196.2) after training (see Figure 9.14).

The blood flow to the forearm was reduced after sub-maximal exercise, as seen in Figure 9.12. When the maximum decrease was expressed as a change from the resting value, the largest fall occurred after the period of training (93.1% [-101.8 to 55.7] compared to 76.3% [-90.8 to 0.0]). Comparison of the individual differences between the control and training period showed the training programme reduced sub-maximal forearm blood flow by 8.8% (-55.2 to 26.3).

The mean forearm blood flow increased by 9.2% (-25.5 to 152.2) after training.

None of the changes in blood flow were significant.

Figure 9.13 Individual and median (95% CI) changes in peak calf blood flow after sub-maximal exercise.

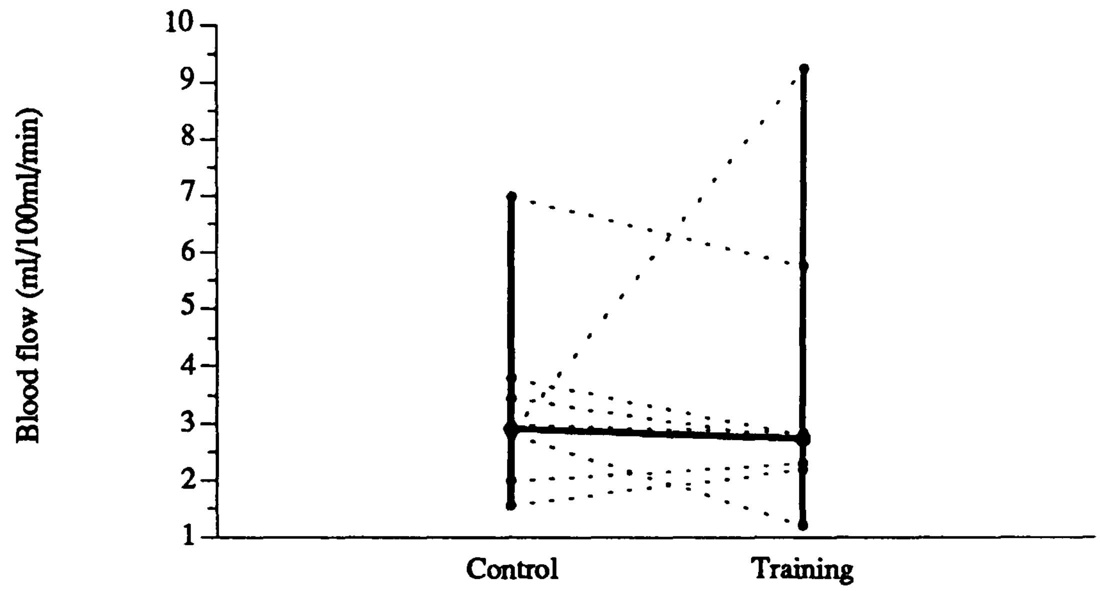
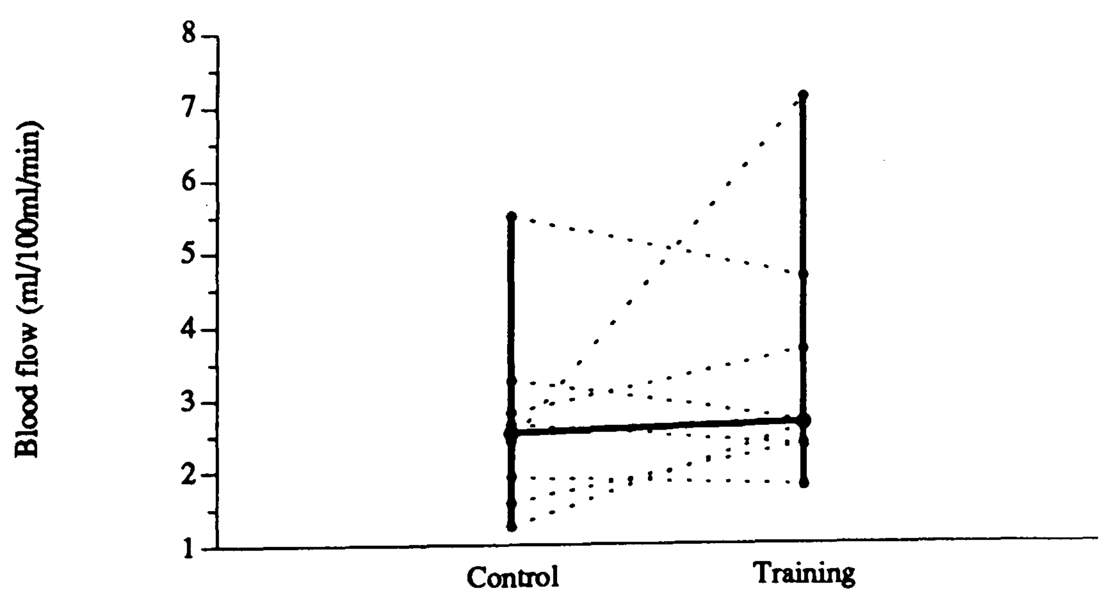


Figure 9.14 Individual and median (95% CI) changes in mean lower leg blood flow after sub-maximal exercise.



The relationship between the increase in lower leg blood flow and decrease in forearm blood flow after sub-maximal exercise was investigated. There was only a moderate correlation between the changes after training (r_s -0.45) whilst that during the control period was poor (r_s -0.28).

9.2.5 DISCUSSION OF CHANGES IN LIMB BLOOD FLOW

The decrease in resting blood flow to the lower leg may indicate greater extraction of oxygen from the arterial blood as a result of the training programme. The increase in mean and peak lower leg blood flow after sub-maximal exercise does not support this explanation and it has been established that patients with chronic heart failure already have increased oxygen extraction at rest compared to healthy subjects. The decrease in blood flow may represent improved distribution of blood within the lower leg and muscle tissue. This would facilitate a scenario similar to improved matching of ventilation/perfusion at the lungs to occur within the muscles of the lower leg thereby decreasing the demand for blood flow at rest.

Alternatively, a decrease in resting cardiac output would explain the reduced resting blood flow in both the leg and forearm. The results of the exercise tolerance tests showed only minimal decreases in resting cardiac index and these were within the margin of error for the measurement technique.

The proportional increase in peak leg blood flow above resting value was mainly attributable to the decreased resting values, as the values in 100ml/ml/min showed a small decrease after training. Consequently after training there appeared to be a greater difference between resting and exercise leg blood flow than in the control period.

The increase in blood flow to the leg after training may have been partly due to the increase in sub-maximal cardiac index and partly due to increased redistribution of blood from inactive to active muscles. The latter is supported by the greater correlation coefficient for changes in blood flow between the lower leg and forearm after training.

9.3 CHANGES IN RESPIRATORY MEASUREMENTS

9.3.1 CHANGES IN OXYGEN CONSUMPTION

All patients showed an increase in peak oxygen consumption, expressed as METs, after training (see Figure 9.15) with a significant mean improvement of 17.1% (11.6 to 22.6). After one month of training peak VO_2 consumption had increased by 8.4% (2.3 to 12.8) which was not significant.

A significant correlation was found between the increases in peak oxygen consumption and cardiac index (r_s 0.69).

Overall, VO_2 consumption increased after training at both sub-maximal work loads (see Figures 9.16 and 9.17) although it did decrease in some patients. At the work load equivalent to 50% peak VO_2 uptake it increased by 2.8% (-5.3 to 10.9), and by 6.2% (-7.8 and 20.3) at the fixed work load.

9.3.2 CHANGES IN CARBON DIOXIDE PRODUCTION

Peak VCO_2 production increased by 14.2% (-0.8 to 29.4) after training, but it was seen to fall in some patients (see Figure 9.18).

The variation in VCO_2 production was more pronounced at sub-maximal work loads.

Figure 9.15 Changes in individual and mean (95% CI) peak METs.
*p<0.05

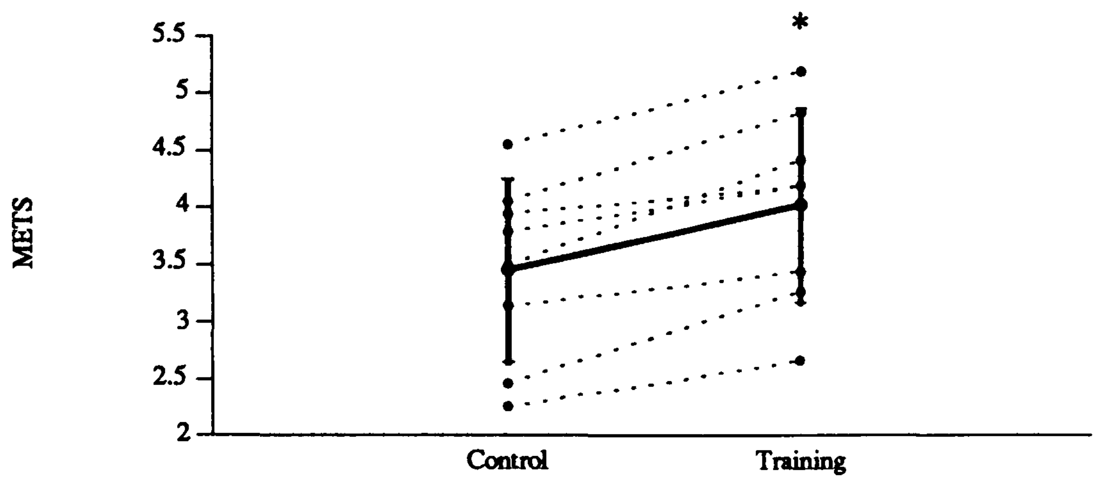


Figure 9.16 Changes in individual and mean (95% CI) METs at sub-maximal load equivalent to 50% peak VO_2 uptake at entry.

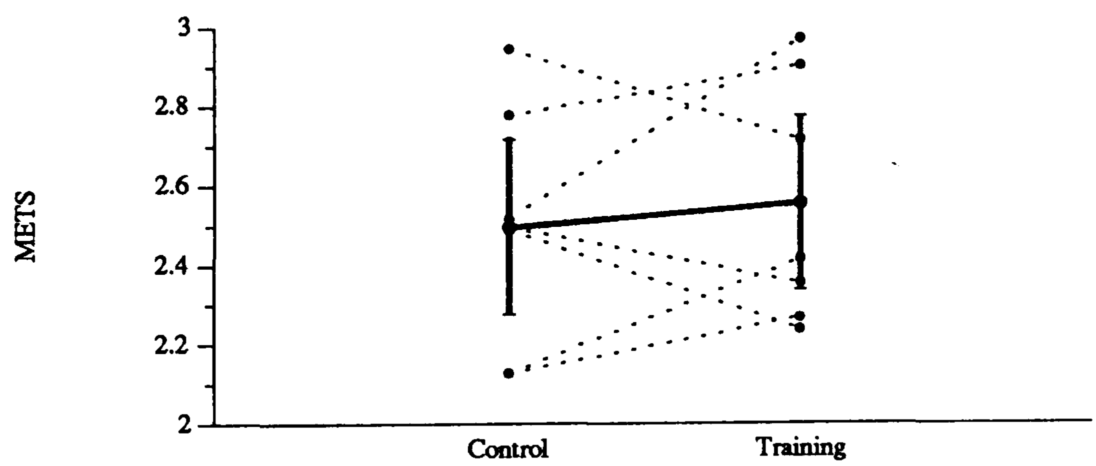


Figure 9.17 Changes in individual and mean (95% CI) METs at work load 03 of treadmill protocol.

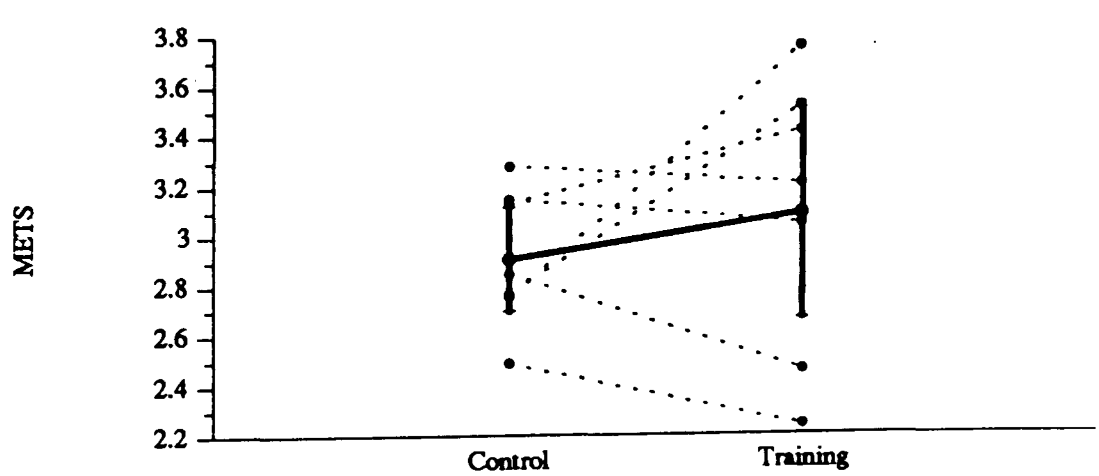


Figure 9.19 indicates an overall reduction in VCO_2 after training, but when the changes of the individual patients were expressed as a percentage of the control value, a mean increase of 3.1% (-7.4 to 13.6) was shown after training. At the fixed work load a mean decrease of 1.7% (-10.4 to 13.8) was seen after training, but as the confidence interval indicates, this encompassed a large variation in VCO_2 production (see Figure 9.20).

9.3.3 CHANGES IN MINUTE VENTILATION

Peak VE decreased by 8.8% (-27.3 to 36.2) after training, although one patient showed a large increase which is reflected in the wide confidence interval (see Figure 9.21).

Small but differing changes were seen after training for the two sub-maximal work loads (see Figures 9.22 and 9.23).

After training VE decreased at the work load equivalent to 50% peak VO_2 uptake by 1.9% (-9.2 to 13.3), and by 1.2% (-14.9 to 17.3) for the fixed work load.

The small size of the changes for the group are partly due to small changes in VE, but also the variability in the direction of change.

9.3.4 CHANGES IN THE RELATIONSHIP OF MINUTE VENTILATION AND CARBON DIOXIDE PRODUCTION

An example of a plot between VE and VCO_2 is shown in Figure 9.24.

The median gradient of the slope VE/VCO_2 decreased from 2.65 (1.61 to 3.29) for the control period to 2.61 (1.42 to 5.12) after training.

Figure 9.18 Changes in individual and mean (95% CI) peak VCO_2.

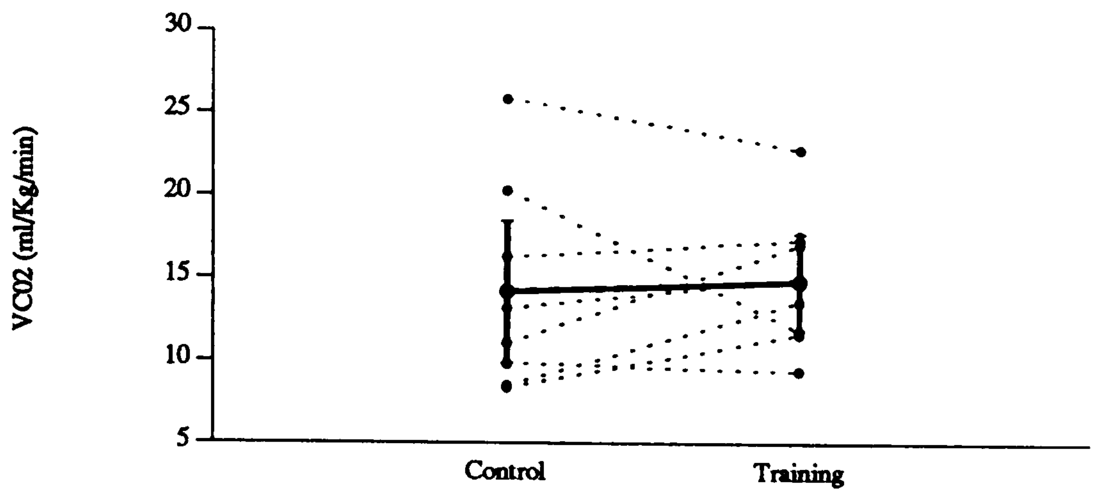


Figure 9.19 Changes in individual and mean (95% CI) VCO_2 at sub-maximal load equivalent to 50% peak VO_2 uptake at entry.

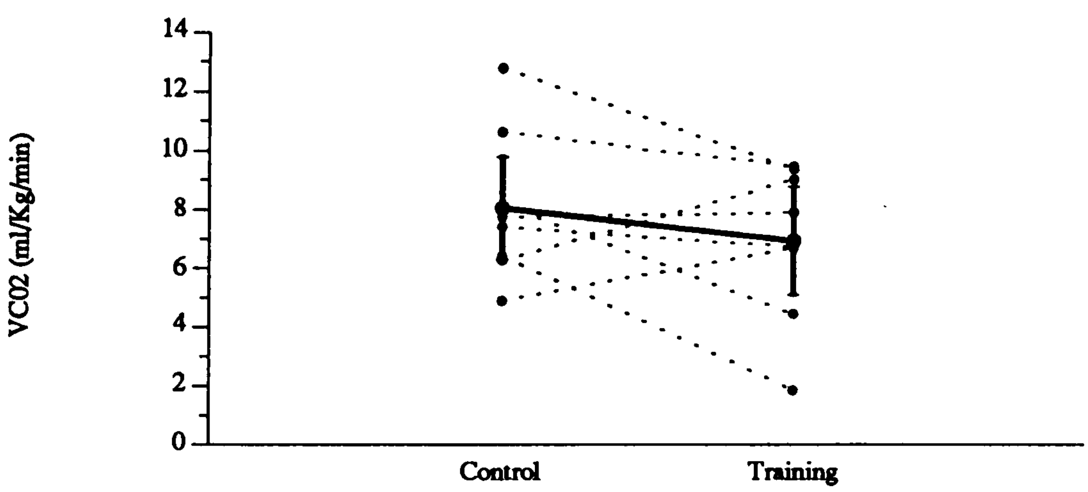


Figure 9.20 Changes in individual and mean (95% CI) VCO_2 at work load 03 of treadmill protocol.

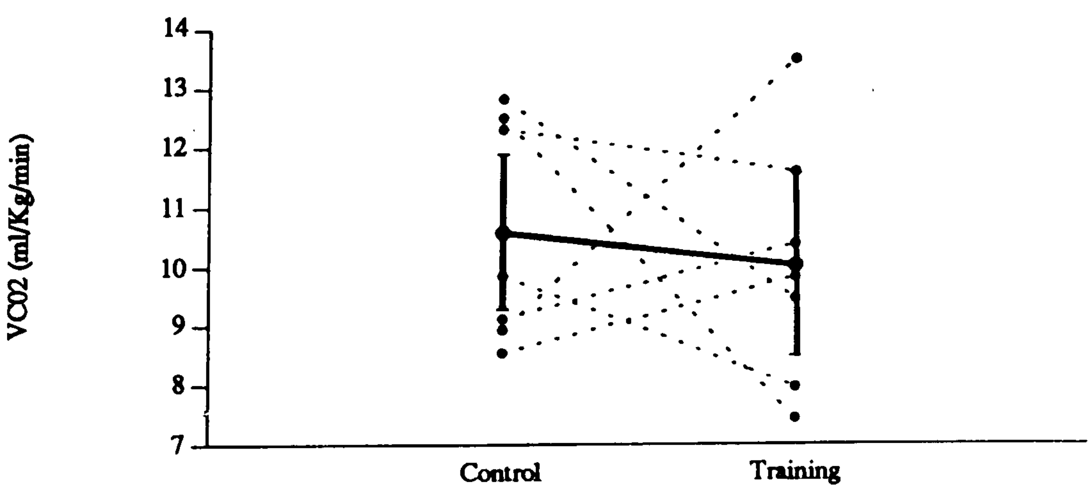


Figure 9.21 Changes in individual and median (95% CI) peak VE.

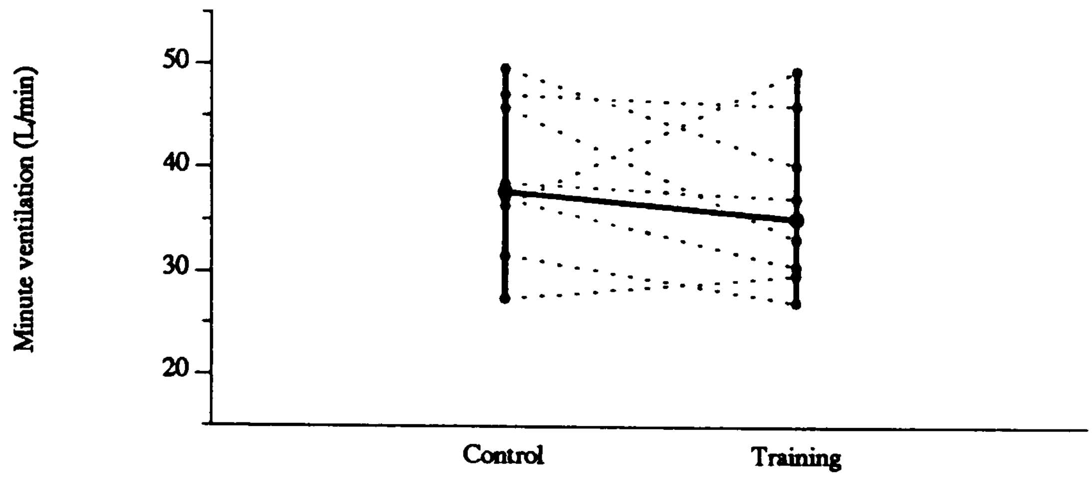


Figure 9.22 Changes in individual and mean (95% CI) VE at sub-maximal load equivalent to 50% peak VO_2 uptake at entry.

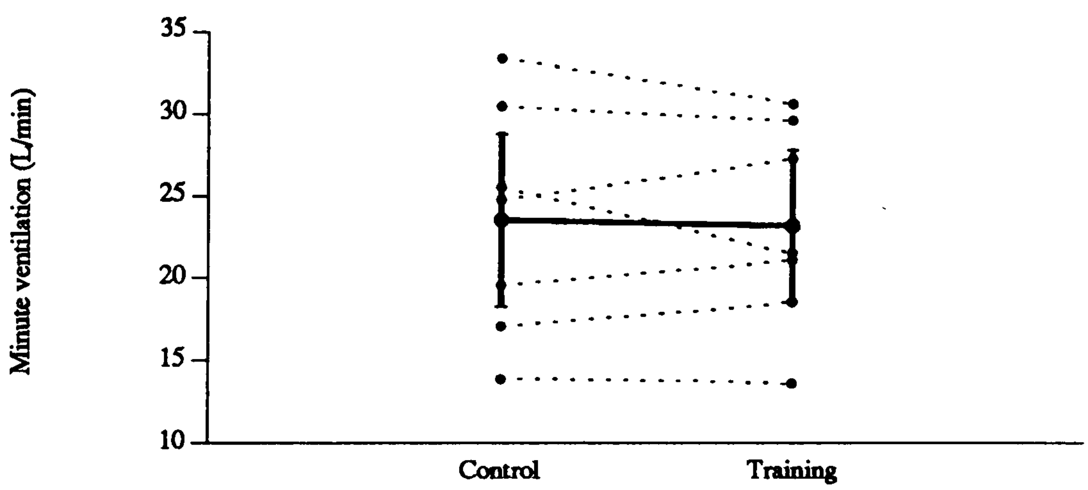


Figure 9.23 Changes in individual and mean (95% CI) VE at work load 03 of treadmill protocol.

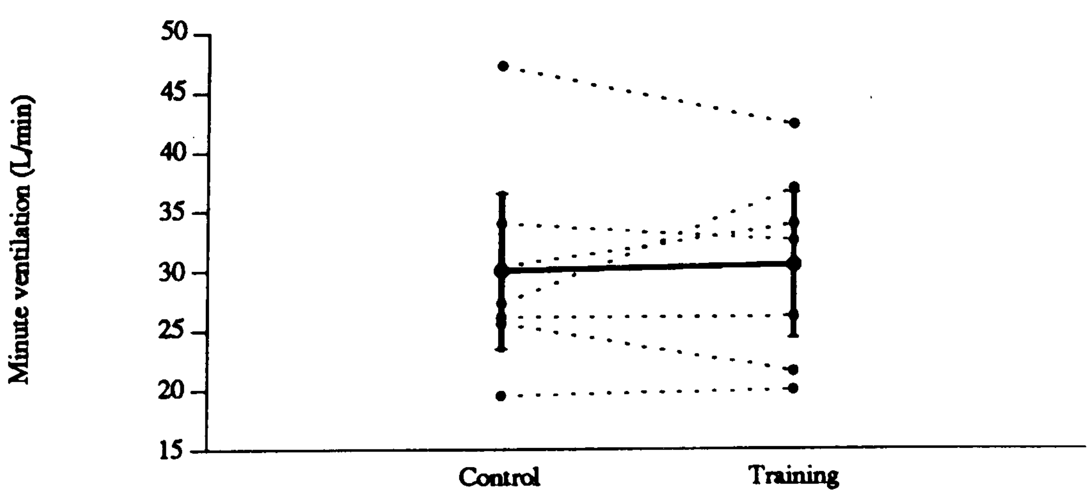


Figure 9.25 shows the variability of the changes, with both increases and decreases in slope occurring after training. The width of the confidence interval was much larger after training than during the control period.

When the differences after training were expressed as a percentage change from the control period, the median showed a small decrease in the slope (4% [-40.2 to 55.6]).

An example of the plot of carbon dioxide ventilatory equivalent against exercise time is shown in Figure 9.26.

In most of the subjects the point representing the least VE/VCO_2 (i.e. the trough of the plot) occurred at a later time after training (see Figure 9.27).

Overall, training delayed the mean point of maximum ventilatory efficiency by 53 seconds (-63 to 169), which was not significant.

No consistent changes were seen after training for the values of VE/VCO_2. In some patients there was very little difference between the pattern and magnitude of control and training measurements, whilst in others the control values were larger than those after training.

9.3.5 CHANGES IN TIME FOR EXERCISE TOLERANCE TEST

After training the mean treadmill exercise time increased by 7.6% (-2.4 to 18.9). Figure 9.28 shows the variability of the changes, with the results varying both in magnitude and direction of change.

The results of the self-paced walk test (an informal measure of exercise capacity) showed the walking speed of the patients generally increased after training (see Figures 9.29 and 9.30). The mean times for the normal and fast pace walks both decreased by 3.5% (-5.3 to -1.6; -8.8 to 1.7

Figure 9.24 Plot for an individual patient showing changes in VE and VCO_2

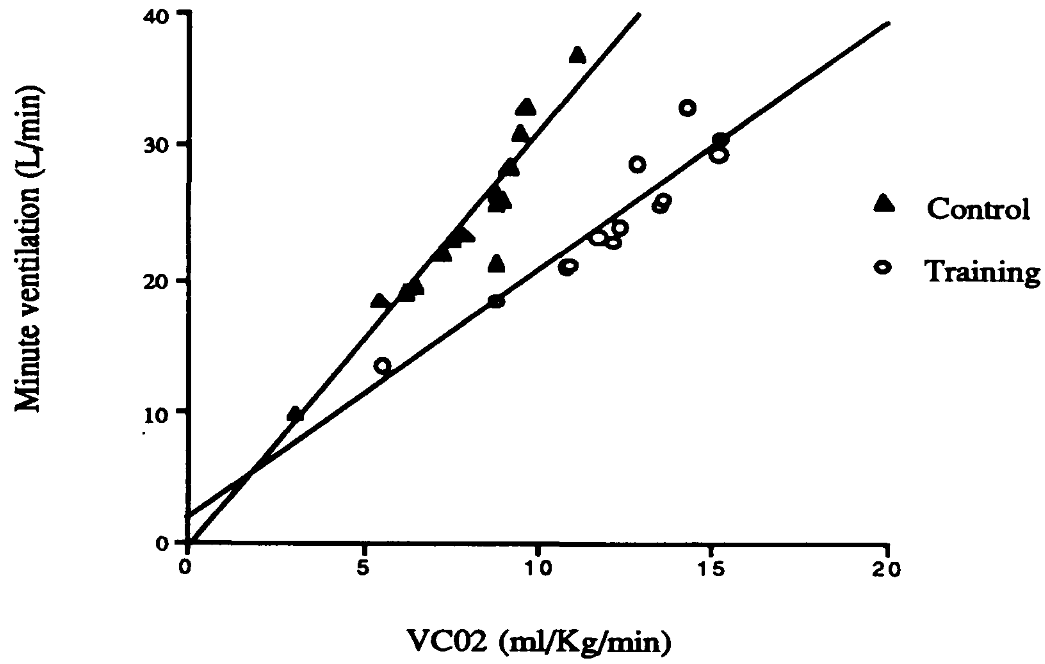


Figure 9.25 Individual and median (95% CI) changes in the slope for VE/VCO_2

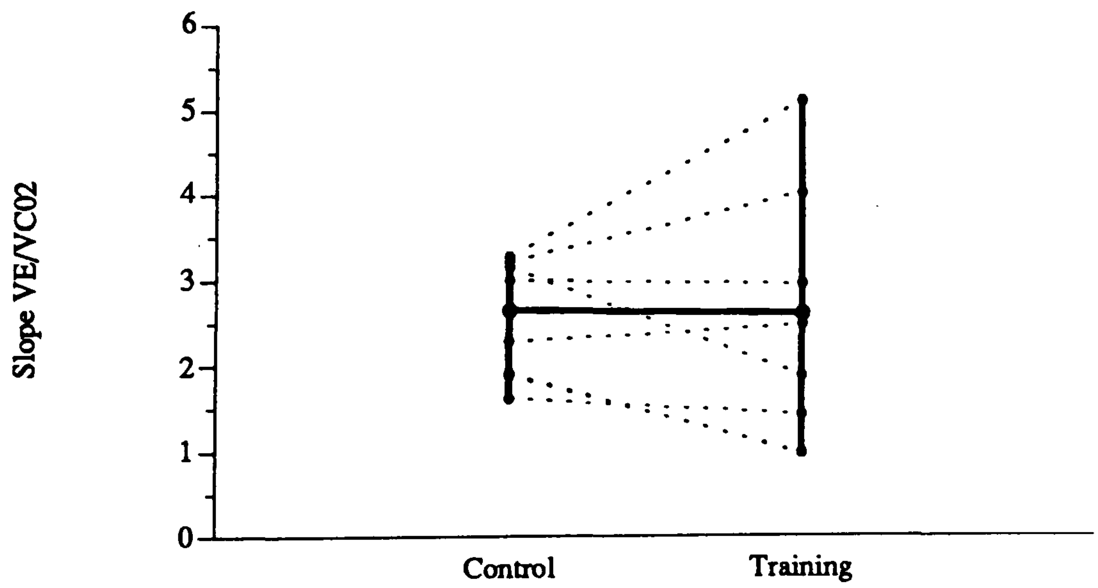


Figure 9.26 Plot for an individual patient showing changes in ventilatory equivalent for carbon dioxide against time.

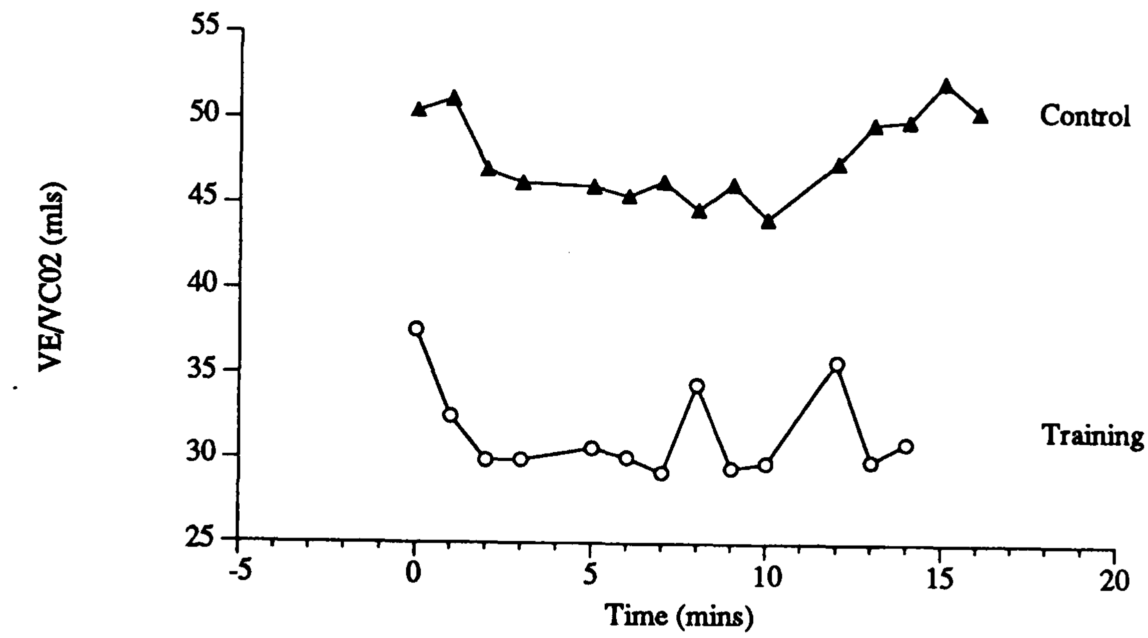


Figure 9.27 Individual and mean (95% CI) changes in exercise time for lowest value of carbon dioxide ventilatory equivalent

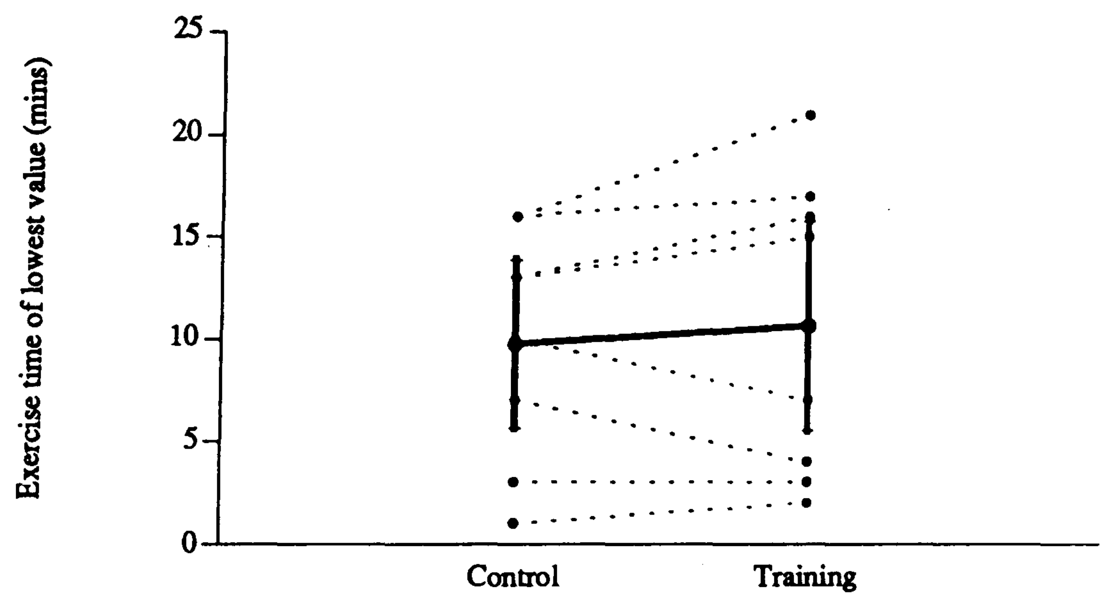


Figure 9.28 Individual and mean (95% CI) changes in treadmill time.

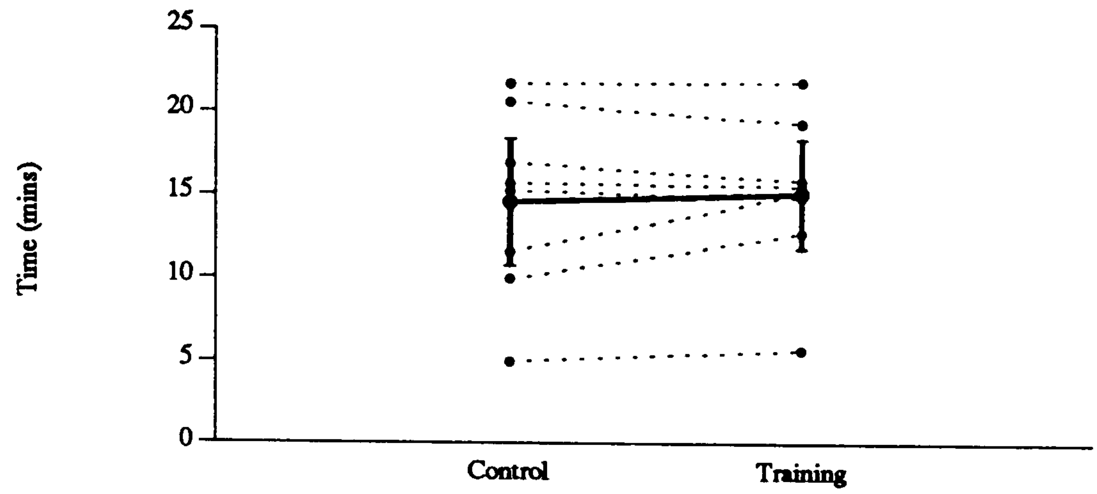


Figure 9.29 Individual and mean (95% CI) changes for time to complete normal paced walk test.

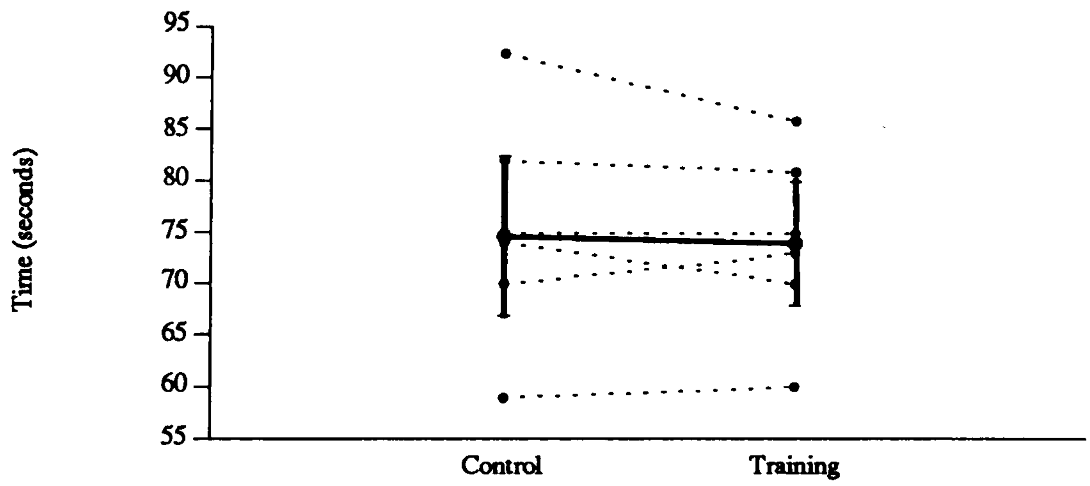
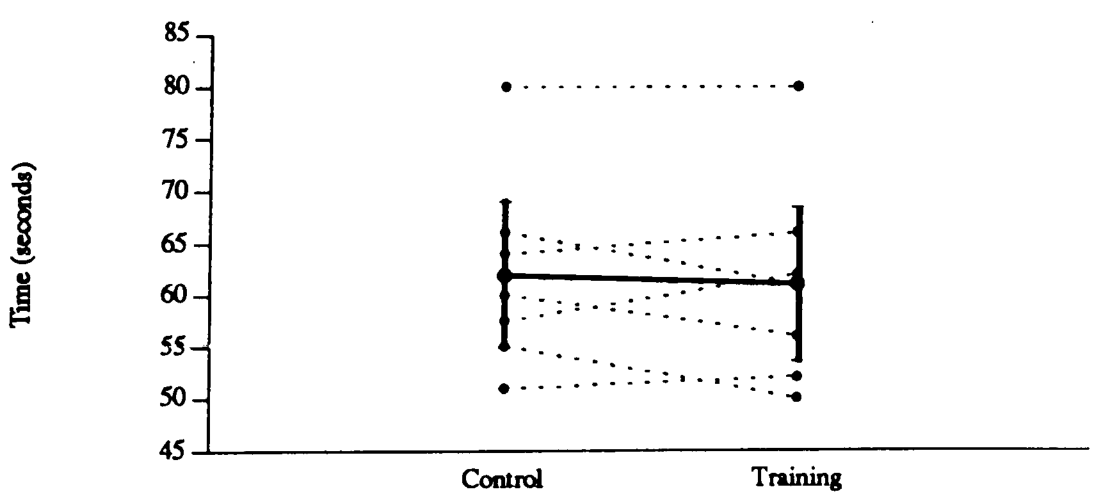


Figure 9.30 Individual and mean (95% CI) changes for time to complete fast paced walk test



respectively) after training, but there was greater variability in the times of the fast walk.

There was a significant correlation between the change in time to complete the fast walk test and the increase in total ambulatory activity measured by the activity monitor (r_S 0.95).

9.3.6 DISCUSSION

The large improvements in peak oxygen consumption and cardiac index after training were not accompanied by similar changes in treadmill time, suggesting factors other than oxygen delivery influenced exercise time.

No significant correlations were found between the changes in treadmill time and any of the other physiological or psycho-social measurements, therefore it is difficult to determine the main factor influencing exercise time in this study. However, the increase in carbon dioxide production at peak exercise reflects the improvement in exercise performance and the similar increases in peak oxygen consumption would suggest the increase in treadmill exercise time was primarily due to improvement in aerobic function.

Only minimal improvements were seen in the walk tests after training, suggesting the exercise programme had not influenced the intensity of ambulatory activity. This is contradicted by the correlation between increased speed for the fast walk test and total activity time, which suggests a relationship between increased speed and the time spent walking. A correlation would have been anticipated between the improvement in speed for the normal walk and the increased time spent walking at the medium pace, but this did not occur.

The paucity of correlations between the different methods of assessing exercise tolerance indicates that improvements in one aspect of the patient did not relate to changes in other areas. Consequently the selection of outcome measures needs to extend beyond physiological measures to provide an holistic view of the effects of any form of intervention.

The significant increase in peak oxygen consumption after two months of exercise training indicates an improvement in aerobic function in the exercising muscles of these patients with a resultant increase in exercise tolerance. This, together with the decrease in resting heart rate indicates peripheral adaptation whilst the increase in peak cardiac index supports a central training effect.

The changes in blood flow to the lower leg after training did not suggest an increase in arterio-venous oxygen difference which would have been anticipated with a peripheral training response, although the limitations of the technique have been previously discussed in part A. This would suggest the increased oxygen consumption was due to increased delivery to the active tissues, rather than increased extraction.

The decrease in peak minute ventilation suggests an improvement in ventilatory efficiency, as it would otherwise have been expected to increase with increased carbon dioxide production and oxygen consumption. This is partly supported by the small decrease in slope of the plot VE/VCO_2, which indicates an improvement in ventilatory efficiency, and by the delay in reaching maximum efficiency as shown by the changes in carbon dioxide ventilatory equivalents. From this study it is not possible to determine the cause of the improved efficiency in ventilation, but it may be due to improved ventilation/perfusion match in the lungs or reduced capillary wedge pressure.

Only small changes were found in all respiratory measurements after training at both sub-maximal work loads, and these were generally accompanied by wide confidence intervals, making interpretation of any changes difficult. The largest changes were seen in oxygen consumption, but carbon dioxide production hardly altered, suggesting the mean changes in oxygen uptake were influenced by the large variation in results.

CHAPTER 10

DISCUSSION

This group of patients with chronic heart failure, who in the past have been considered a high-risk for inclusion in exercise programmes, showed widespread responses to training after completing a two month exercise programme.

The activity monitor indicated the patients were active for a longer proportion of the day and the intensity of their activity increased. This was accompanied by an improvement in their quality of life, particularly in their psychological status. This aspect of recovery may be linked to the improvement in physiological state, or it may be independent of the latter and reflect a general feeling of well-being after exercise.

The decrease in peak minute ventilation and slope of VE/VCO_2 seen after training indicates the patients experienced an improvement in ventilatory efficiency which may have been due to improved ventilation/perfusion ratio in the lungs after training, but this was not explored in this study. This improvement would have manifested itself as a decrease in breathlessness but the lack of correlation between this aspect and improvement in treadmill time suggests factors other than dyspnoea determined their exercise time on the treadmill. This aspect has been explored by other workers (Clark et al. 1995; Cowley 1995; Zelis et al. 1988).

The physiological changes suggest both central and peripheral adaptation to training had occurred. This is supported by the increase in peak cardiac index with minimal change in heart rate and the increase in peak oxygen consumption, although there was not any evidence of increased oxygen extraction by the active muscles.

Results from other studies suggest a decrease in blood flow to active muscles after sub-maximal exercise may not be an appropriate indicator for the presence of peripheral training responses with this group of patients.

The basis for this theory lies in the abnormal blood flow and skeletal muscle metabolism which is a feature of patients with chronic heart failure Poole-Wilson (1992) stated skeletal blood flow is up to five times less in patients than in healthy subjects and the histological changes are not typical of disuse atrophy. In contrast, Wiener et al (1986) found that although limb blood flow in some patients remained normal, oxidative metabolism, as determined by the ratio of inorganic phosphate to phosphocreatine, was abnormal. They suggested the altered metabolism may have been due to the ineffective distribution of intra-muscular blood flow and a decrease in mitochondrial volume.

Studies which have investigated histological changes in skeletal muscle have observed changes indicative of increased anaerobic metabolism. Drexler et al. (1992) found an increase in the proportion of type II muscle fibres and decreases in mitchondrial volume and cristae and cytochrome oxidase activity. The presence of these changes were dependent on the severity and duration of the condition. Massie et al (1987) found similar changes but determined they were independent of impaired blood flow. When allowances were made for the differences in muscle mass between patients and healthy subjects, Minotti et al (1992) found metabolic changes still persisted, indicating atrophy was not the only factor affecting exercise performance, but biochemical and histological changes similar to those of deconditioning were also involved.

Using invasive methods to determine oxygen extraction, Wilson et al (1993) determined the level of oxygen extraction in patents was dependent on blood flow, and those patients who maintained normal blood flow also demonstrated normal levels of extraction both at rest and during exercise. Takata et al. (1990) and Zelis et al. (1974) found patients with chronic heart failure had higher levels of oxygen extraction than healthy subjects, presumably to compensate for a reduction in muscle blood flow, but their oxygen consumption was still lower than normal.

Against this background, measurements of oxygen consumption at the active tissues would be a more appropriate method of identifying peripheral adaptation to training rather than a decrease in sub-maximal blood flow, which is an indirect method suggesting changes in arterio-venous oxygen difference. This is because an increase in blood flow, accompanied by a decrease in arterio-venous oxygen difference, would indicate skeletal metabolism was assuming a more 'normal' profile of activity in response to the period of training.

Similar changes in peak cardiac index and oxygen uptake after training were also noted by Coats et al. (1992) which reflects the similarlity in design of the two studies. Although other studies of similar length of training, and which measured both oxygen uptake and cardiac output, found increases in peak oxygen uptake (Hoffman et al. 1987; Squires et al 1987; Sullivan et al. 1988) they did not observe changes indicating the presence of central adaptation. All of these studies exercised at a similar intensities and the differences in results may reflect differences in the fequency and length of each exercise session. Both Coats et al (1990) and Sullivan et al (1988) commented on the relationship between compliance to the exercise programme and physiological improvement.

The increase in blood flow to the legs after training may have been the result of increased release of endothelially-derived relaxing factors (Dubach and Froelicher 1989). The resultant vasodilatation in the active muscles, together with the increase in sub-maximal cardiac index, would increase oxygen delivery to the active muscles and increase their oxidative capacity. This combination of events would be beneficial to patients with chronic heart failure for whom part of their restricted exercise tolerance has been attributed to reduced skeletal blood flow and oxygen delivery.

Some of the additional blood flow to the legs after exercise was due to an increase in redistribution of blood from the inactive forearm muscles, but the mean sub-maximal forearm blood flow also increased, indicating the increase in blood flow was not restricted to the trained muscles.

The reported redistribution of blood from active to inactive muscles during exercise (Poole-Wilson et al. 1988) was not seen in this study due to the predominance of NYHA class II patients.

Beneficial changes in structure, metabolism and biochemical function of skeletal muscle have been observed after training, culminating in an increase in oxidative capacity (Adamopoulos et al. 1993; Sullivan et al. 1988), but none of these aspects were investigated in this study.

The lack of carry-over effects between the training and control periods illustrate the gains of the exercise programme were short lived. This was also seen in a similar study by Coats et al. (1992) and this emphasises the importance of continued, regular exercise for this group of patients if the improvements are to be maintained.

CHAPTER 11

CONCLUSIONS ON CARDIAC REHABILITATION

These two studies indicate cardiac rehabilitation has a more pronounced effect on patients with chronic heart failure than with patients recovering from an uncomplicated MI.

The development of the electronic pedometer resulted in a measuring tool which provides an objective, valid and reliable method of measuring ambulatory activity. It not only yields information concerning the quantity of walking, but also the quality of ambulatory activity. It has the advantage over other available pedometers in that it identifies when walking has been performed at a faster rate or longer individual periods. This provides more detailed information on changes of walking activity in patients which is not otherwise available in an objective form. However, it requires a high compliance from patients and can only provide information during periods when the shoes are worn.

Both of these studies are limited by the small numbers of patients involved and the restraints of time did not allow long term follow-up assessments. There is no published data concerning the effects of exercise training on the mortality of patients with chronic heart failure and this is probably due to the small sample sizes of most published papers.

11.1 COMPARISON OF TRAINING RESPONSES

These investigations show both groups of patients derived benefits from a short-term exercise programme. Patients with chronic heart failure demonstrated significant improvements in all the areas measured, whilst those recovering from a MI mainly showed significant changes in psycho-social parameters.

Indications of both central and peripheral adaptation to exercise training were observed in the patients with chronic heart failure, with the post MI patients showing smaller, predominantly peripheral, responses but some indicators of central change were observed.

Some of the changes in psycho-social parameters were probably the result of physiological responses to training, but others may have been attributable to an increased feeling of well-being. Whatever the origin, an improvement in physiological state is of limited benefit to the patient unless it translates to an improvement in quality of life.

In both groups there was a disparity between the improvements in physiological function, measured by exercise tolerance tests, and informal measures of exercise performance and rehabilitation status. This highlights the need for an holistic assessment of intervention effects.

Whilst some studies have included informal outcome measures (Blackwood et al. 1990; Coats et al. 1992; Cowley et al 1991; Gorkin et al 1993; Oldridge et al. 1991) the paucity of appropriate sensitive, valid and reliable measuring tools has probably hindered their general acceptance and use.

11.2 IMPLICATIONS OF FINDINGS FOR CARDIAC REHABILITATION

A report by the working group of the British Cardiac Society (1995) found an increase in the provision of cardiac rehabilitation programmes throughout the UK since 1989, but concern has been expressed regarding its limited availability.

The results from these investigations suggest patients recovering from a MI derived only small benefit from completing all components of the early rehabilitation programme, and none from only attending the education sessions. In contrast, the patients with chronic heart failure achieved greater benefit in all of the areas measured after a short period of exercise training. The exercise programmes were safe for all patients and no adverse events occurred during either the periods of exercise testing or whilst performing the exercise regime.

Whilst the results of the MI study appear to contradict those of other studies, it has to be placed in the context of changes in the medical management of this group of patients.

Most of the previous studies that reported large improvements in physiological function after exercise training were undertaken when early mobilisation was discouraged and patients did not join an exercise programme until six to eight weeks after infarction. The use of thromobolytic therapy was also not a feature of their management.

The combination of these factors resulted in de-conditioned patients with larger areas of myocardial damage. This provided the opportunity for a greater improvement in exercise tolerance compared to the present study, where in the latter the patients had reduced myocardial damage, earlier in-patient mobilisation and were recruited into the rehabilitation programme within two weeks after infarction.

The improvement in management of acute MI means more people survive an event, resulting in an increase in demand on services and a rise in the number of high-risk patients (Pashkow 1993).

Against this background several papers have raised the issue of whether formal, in hospital cardiac rehabilitation programmes should be available to all patients, or whether the low-risk patients without any problems should be encouraged to participate in non-hospital based programmes, or be responsible for their own rehabilitation with the provision of self-help facilities (Bar et al. 1992; Chua and Lipkin 1993; DeBusk 1992: Franklin et al. 1992: Haskell 1994; Lewin 1992; Lindsay et al. 1991; Sparks et al. 1993).

If entry into a rehabilitation programme is selective, a prediction model will need to be developed to determine those who would derive the most benefit. Some work has already been performed in this area, but it still remains in its infancy (van Dixhoorn et al. 1990; Gorkin et al 1991; Myers and Froelicher 1990; Oldridge and Streiner 1990; Volterrani et al 1994).

No research has been published on alternative physical methods of deriving a training effect in patients who are unable to perform lower limb exercise, such as those with orthopaedic or respiratory problems. Adamopoulos et al. (1995) found improvements similar to those derived from exercise training could be achieved with short-duration inotrope therapy in patients with chronic heart failure. The benefits of artificially stimulating skeletal muscles in this patient group has not yet been reported.

The provision of cardiac rehabilitation in terms of cost effectiveness and re-hospitalisation has not been explored within the UK.

The efficacy of cardiac rehabilitation in its various forms needs to be reassessed in harness with changes in the management of patients with cardiac disease, especially if these involve changes in drug prescribing habits

The results from the study with patients recovering from an uncomplicated MI suggest the emphasis of cardiac rehabilitation should be placed on early mobilisation to avoid the effects of de-conditioning and maximise the benefits of thrombolysis. If necessary, psycho-social support could be provided by a variety of non-hospital based schemes and this would reduce the need for out-patient programmes. The latter could then be directed at patients with chronic heart failure, who were shown to derive greater benefit from a period of exercise training.

REFERENCES

Adamopoulos S, Coats AJS, Brunotte F, Arnolda L, Meyer T, Thompson CH, Dunn JF, Stratton J, Kemp GJ, Radda GK, Rajagopalan B. Physical training improves skeletal muscle metabolism in patients with Chronic Heart Failure. J Am Coll Cardiol 1993; 21: 1101-6

Adamopoulos S, Piepoli M, Qiang F, Pissimissis E, Davies M, Bernardi L, Forfar C, Sleight P, Coats A. Effects of pulsed b-stimulant therapy on b-adrenoceptors and chronotrophic responsiveness in chronic heart failure. Lancet 1995; 345: 344-9

Affleck JW, Aitken RCB, Hunter JAA, McGuire RJ, Roy CW. Rehabilitation status; a measure of medisocial dysfunction. Lancet 1988; i: 230-3

Altenkirch HU, Koch G, Koralewski HE. Variability and reproducibilty of arterial and venous circulation parameters in the forearm and calf measured at one-week intervals. VASA 1990; 19: 21-5

American College of Sports Medicine. Guidelines for exercise testing and prescription. 4th ed. Philadelphia: Lea and Febiger 1991: Chapters 5 and 6

American Heart Association. Medical/Scientific statement, Statement on exercise. Circulation 1992; 86: 340-4.

Arvan S. Exercise performance of the high risk acute myocardial infarct patient after cardiac rehabilitation. Am J Cardiol 1988; 62: 197-201

Astrand P-O; Rodahl K. Textbook of work physiology. 3rd ed. New York: McGraw-Hill, 1986: Chapter 10

Bar FW, Hoppener P, Diederiks J, Vonken H, Bekkers J, Hoofd W, Appels A, Wellens HJJ. Cardiac rehabilitation contributes to the restoration of leisure and social activities after myocardial infarction. J Cardiopulmonary Rehab 1992; 12: 117-25.

Batin PD. Studies in cardiovascular haemostasis [MD Thesis]. University of Nottingham 1994

Beaver WL, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. J Appl Physiol; 1986; 60: 2020- 27

Bertie J, King A, Reed N, Marshall AJ, Ricketts C. Benefits and weaknesses of a cardiac rehabilitation programme. J R Coll Physicians Lond 1992; 26: 147-51

Bethell HJ. Exercise in post infarction rehabilitation. Br J Clin Pract 1992; Summer 46: 116-22

Bethell HJ, Mullee MA. A controlled trial of community based coronary rehabilitation. Br Heart J 1990; 64: 370-5

Blackwood R, Mayou RA, Garnham JC, Armstrong C, Bryant B. Exercise capacity and quality of life in the treatment of heart failure. Clin Pharmacol Ther 1990; 48: 325-32.

Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; i: 307-10

Blodgett C, Pekarik G. Program evaluation in Cardiac Rehabilitation II; outcome evaluation procedures. J Cardiopulmonary Rehab 1987; 7: 374-82.

Blood SM, Ades PA. Effects of beta-adrenergic blockade on exercise conditioning in coronary patients: A review. J Cardiopulm Rehabil 1988; 8:141-4

Blumenthal JA, Rejeski WJ, Walsh-Riddle M, Emery CF, Miller H, Roark S, Ribisl PM, Morris PB, Brubaker P, Williams RS. Comparison of high and low-intensity exercise training early after acute myocardial infarction. Am J Cardiol 1988; 61: 26-30

Bowling A. Measuring health. Buckingham: Open University Press 1991: Chapters 1, 3 and 4

Brezinsky D, Stone PH, Muller JE, Tofler GH, Davis V, Parker C, Hartley LH, Braunwald E. Prognostic significance of the Karnofsky Performance Status score in patients with acute myocardial infarction; comparison with LVEF and the exercise treadmill test. Am Heart J 1991; 121: 1374-81

British Cardiac Society. A report of a working group of the British Cardiac Society: Cardic rehabilitaion services in the United Kingdom 1992. Br Heart J 1995; 73: 201-2

Brooks GA. Current concepts in lactate exchange. Med Sci Sports Exerc 1991; 23: 895-906

Buller NP, Poole-Wilson PA. Mechanism of the increased ventilatory responses to exercise in patients with chronic heart failure. B Heart J 1990; 63: 281-3

Burek KA, Kirscht J, Topol EJ. Exercise capacity in patients 3 days after acute, uncomplicated myocardial infarction. Heart and Lung 1989; 18; 575-80

Campbell ME, Hughson RL, Green HJ. Continuous increase in blood lactate concentration during different ramp exercise protocols. J Appl Physiol 1989; 66: 1104-7

Cassem NH, Hackett TP. Psychological rehabilitaion of myocardial infarction patients in the acute phase. Heart and Lung 1973; 2: 382-8.

Cavagna GA, Margaria R. Mechanics of walking. J Appl Physiol 1966; 21: 271-8

Cay EL. Psychological problems in patients after myocardial infarction. Adv Cardiol 1982; 29: 108-12

Certo CM. History of cardiac rehabilitation. Phys Ther 1985; 65: 1793-5

Chua TP, Anker SD, Harrington D, Coats AJS. Inspiratory muscle strength is a determinant of maximum oxygen consumption in chronic heart failure. Br Heart J 1995; 74: 381-5

Chua TP, Lipkin DP. Cardiac rehabilitation shoud be available to all who would benefit. Br Med J 1993; 306: 731-2

Clark AL, Sparrow JL, Coats AJS. Muscle fatigue and dyspnoea in chronic heart failure: two sides of the same coin? Eur Heart J 1995; 16: 49-52

Clausen JP. Circulatory adjustments to dynamic exercise and effects of physical training in normal subjects and in patients with coronary artery disease. Prog. Cardiovascular Dis 1976; 18: 459-95

Coats AJS, Adamopoulos S, Meyer TE, Conway J, Sleight P. Effects of physical training in chronic heart failure. Lancet 1990; 335: 63-6

Coats AJS, Adamopoulos S, Radaelli A, McCane A, Meyer TE, Bernardi L, Solda PL, Davey P, Ormerod O, Forfar C, Conway J, Sleight P. Controlled trial of physical training in chronic heart failure; Exercise performance, haemodynamics, ventilation and autonomic function. Circulation 1992; 85: 2119-31

Cobb FR, Williams RS, McEwan P, Jones RH, Coleman RE, Wallace AG. Effects of exercise training on ventricular function in patients with recent myocardial infarction. Circulation 1982; 66; 100-8

Conn EH, Williams RS, Wallace AG. Exercise responses before and after physical conditioning in patients with severly depressed left ventricular function. Am J Cardiol 1982; 49: 296-300

Coplan NL, Gleim GW, Nicholas JA. Principles of exercise prescription for patients with coronary artery disease. Am Heart J 1986; 112: 145-9

Corbally MT, Brennan MF. Non-invasive measurement of regional blood flow in man. Am J Surgery 1990; 160: 313-21

Coronary Prevention Group. Coronary heart disease: Statistics 1992. London: The Coronary Prevention Group, 1992

Cowley AJ. Are breathlessness and fatigue in chronic heart failure due to the same pathophysiological abnormality? Eur Heart J 1995; 16: 1-2

Cowley AJ, Fullwood LJ, Muller AF, Stainer K, Skene AM, Hampton JR. Exercise capability in heart failure: is cardiac output important after all? Lancet 1991; 337: 771-3

Cowley AJ, Murphy DT, Stainer K, Murphy J, Hampton JR. A non-invasive method for measuring cardiac output: the effect of christmas lunch. Lancet ii 1986a; 1422-4

Cowley AJ, Skene AM. Treatment of severe heart failure: quantity or quality of life? A trial of enoximone. Br Heart J 1994; 72: 226-30

Cowley AJ, Stainer K, Rowley JM, Hampton JR. Abnormalities of the peripheral circulation and respiratory function in patients with severe chronic heart failure. Br Heart J 1986b; 55: 75-80

Cox T. Coronary heart disease and stress: psychosocial and behavioural factors in rehabilitation. Physio 1986; 72:231-3

Davey P, Meyer T, Coats A, Adamopoulos S, Casadei J, Sleight P. Ventilation in chronic heart failure: effects of physical training. Br Heart J 1992; 68: 473-7

DeBusk RF. Why is cardiac rehabilitation not widely used? West J Med 1992; 156: 206-8

DeBusk RF, Haskell W. Symptom limited v. Heart rate limited exercise testing soon after myocardial infarction. Circulation 1980; 61: 738-43

DeBusk RF, Haskell WL, Miller NH, Berra K, Taylor CB, Berger WE 3rd, Lew H. Medically directed at-home rehabiliation soon after clinically uncomplicated acute myocardial infarction; a new model for patient care. Am J Cardiol 1985; 55; 251-7

DeBusk RF, Houston N, Haskell W, Fry G, Parker M. Exercise training soon after myocardial infarction. Am J Cardiol 1979; 44: 1223-9

Derenowski Fleury J. Wellness motivation in cardiac rehabilitation. Heart and Lung 1991; 20: 3-8

Detry JM, Rousseau M, Vandenbroucke G, Kusumi F, Brasseur LA, Bruce RA. Increased arteriovenous oxygen difference after physical training in coronary heart disease. Circulation 1971; 44: 109-18

Dickstein K, Barvik S, Aarsland T,Snapinn S, Karlsson J., A comparison of methodologies in detection of the anaerobic threshold. Circulation 1990; 81(1 Suppl): II38-II46

van Dixhoorn J, Duivenvoorden HJ, Pool J. Success and failure of exercise training after myocardial infarction: is the outcome predictable? J Am Coll Cardiol 1990; 15: 974-82

Dracup K, Moser DK, Marsden C, Taylor SE, Guzy PM. Effects of a multidimensional cardiopulmonary rehabilitation program on psychological function. Am J Cardiol 1991; 68: 31-4.

Drexler H, Riede U, Munzel T, Konig H, Funke E, Just H. Alterations of skeletal muscle in chronic heart failure. Circulation 1992; 85: 1751-9

Dubach P, Froelicher VF. Cardiac rehabilitation for heart failure patients. Cardiology 1989;76: 368-73

Dunbar CC, Robertson RJ, Baun R, Blandin M, Metz K, Burdett R, Goss FL. The validity of regulating exercise intensity by ratings of perceived exertion. Med Sci Sports Exerc 1992; 24: 94-9

Ehlers KC, Mylrea KC, Waterson CK, Calkins JM. Cardiac output measurements. A review of current techniques and research. Annals Biomed. Engineering 1986; 14: 219-39

Ehsani AA. Mechanisms responsible for enhanced stroke volume after exercise training in coronary heart disease. Eur Heart J 1987; 8 (Suppl G): 9-14

Ehsani AA, Biello DR, Schultz J, Subel BE, Holloszy JO. Improvement of left ventricular contractile function by exercsie training in patients with chronic artery disease. Circulation 1986; 2: 350-8

Ehsani AA, Martin WH, Heath GW, Coyle EF. Cardiac effects of prolonged and intense exercise training in patients with coronary heart disease. Am J Cardiol 1982; 50: 246-54

Elia M, Kurpad A. What is the blood flow to resting human muscle. Clin Sci 1993; 84: 559-63

Erdman RAM, Duivenvoorden HJ. Psychologic evaluation of a cardiac rehabilitation program: A randomized clinical trial in patients with myocardial infarction. J Cardiac Rehabilitation 1983; 3: 696-704.

ESC working group on exercise physiology, physiopathology and electrocardiography. Guidelines for cardiac exercise testing. Eur Heart J 1993; 14: 969-88

Ewart CK, Taylor CB, Reese LB, DeBusk RF. Effects of early post myocardial infarction exercise testing on self-perception and subsequent physical activity. Am J Cardiol 1983; 51: 1076-80

Fagard R, Conway J. Measurement of cardiac output: Fick principle using catheterization. Eur Heart J 1990; 11 (Suppl 1): 1-5

Fletcher GF, Froelicher VF, Hartley LH, Haskell WL, Pollock ML. Exercise standards. Circulation 1990; 82: 2286-2322

Formel PF, Doyle JT. Rationale of venous occlusion plethysmography. Circ Res 1957; 5: 354-6

Foster S, Lopez D, Thomas HM. Pulmonary rehabilitation in COPD patients with elevated PCO_2. Am Rev Respir Dis 1988; 138: 1519-1523

Foster S, Thomas HM. Pulmonary rehabilitation in lung disease other than chronic obstructive pulmonary disease. Am Rev Respir Dis 1990; 141; 601-4

Fox EL, Matthews DK. Physiological basis of physical education and atheletics. 3rd ed. Philadelphia:CBS College publishing, 1981: Chapter 13

Franklin BA, Gordon S, Timmis GC. Amount of exercise necessary for the patient with coronary artery disease. Am J Cardiol 1992; 69:1426-32

Froelicher V, Sullivan M, Myers J, Jensen D. Can patients with CAD receiving beta-blockers obtain a training effect. Am J Cardiol 1985; 55: 155D-161D

Froelicher VF. The effect of exercise on myocardial perfusion and function in patients with coronary heart disease. Eur Heart J. 1987; 8 (Suppl G): 1-8

Gardner MJ, Altman DG. Statistics with confidence-confidence intervals and statistical guidelines. London: Br Med J publications, 1989: Chapters 3 and 8

Gattiker H, Goins P, Dennis C. Cardiac rehabilitation:current status and future directions. West J Med 1992; 156: 183-8

Giannuzzi I, Tavazzi L, Temporelli PL, Corra U, Imparato A, Gattone M, Giordano E, Sala L, Schweiger C, Malinverni C for EAMI. Long term physical training and left ventricular remodelling after Anterior Myocardial Infarction; Results of the exercise in Anterior MI (EAMI) Trial. J Am Coll Cardiol 1993; 22: 1821-9

Gloag D. Rehabilitation of patients with cardiac conditions. Br Med J 1985; 290: 617-20

Goble AJ, Hare DL, MacDonald PS, Oliver RG, Reid MA, Worcester MC. Effect of early programmes of high and low intensity exercise on physical performance after transmural acute myocardial infarction. Br Heart J 1991; 65: 126-31

Godin G, Valois P, Jobin J, Ross A. Prediction of intention to exercise of individuals who have suffered from coronary heart disease. J Clin Psychology 1991; 47: 762-71

Gordon FN, Duncan JJ. Effect of beta-blockers on exercise physiology; implications for exercise training. Med Sci Sports Exerc 1991; 23: 668-76

Gorkin L, Norvell NK, Rosen RC, Charles E, Shumaker SA, McIntyre KM, Capone RJ, Kostis J, Niaura R, Woods P, Hoskins J, Garces C, Handberg E, Ahern DK, Follick MJ. Assessment of Quality of Life as observed from the baseline data of the Studies of Left Ventricular Dysfunction (SOLVD) trial quality-of-life substudy. Am J Cardiol 1993; 71: 1069-73.

Greenland P and Chu JS. Efficacy of cardiac rehabilitation services. With emphasis on patients after myocardial infarction. Ann Intern Med 1988; 109: 650-663

Gulanick M. Is phase 2 cardiac rehabilitation necessary for early recovery of patients with cardiac disease? A randomised controlled study. Heart and Lung 1991; 20: 9-15

Guyatt GH, Thompson PJ, Berman LB, Sullivan MJ, Townsend M, Jones NL, Pugsley SO. How should we measure function in patients with chronic heart and lung disease? J Chron Disease 1985; 38: 517-24

Guyatt GH, Townsend M, Keller J, Singer J, Nogradi S. Measuring functional status in chronic lung disease:conclusions from a randomized control trial. Respir Med 1989; 83: 293-7

Hagberg JM. Physiologic adaptations to prolonged high-intensity exercise trianing in patients with coronary heart disease. Med Sci Sports Exerc 1991; 23: 661-7

Hagberg JM, Ehsani AA, Holloszy JO. Effect of twelve months of intense exercise training on stroke volume in patients with coronary heart disease. Circulation 1983; 67: 1194-9

Hambrecht R, Niebauer J, Fiehn E, Kalberer B, Offner B, Hauer K, Riede U, Schlierf G, Kubler W, Schuler G. Physical training in patients with stable chronic heart failure: effects on cardiorespiratory fitness and ultrastructural abnormalities of leg muscles. J Am Coll Cardiol 1995; 25: 1239-49

Haskell WL. Cardiovascular complications during exercise training of cardiac patients. Circulation 1978; 57: 920-4

Haskell WL. The efficacy and safety of exercise programs in cardiac rehabilitaion. Med Sci Sports Exerc 1994; 26; 815-23

Hentinen M. Teaching and adaptation of patients with myocardial infarction. Int J Nurs Stud 1986; 23: 125-38

Hellerstein HK, Franklin BA. Exercise testing and prescription. In: Wenger NK and Hellerstein HK, eds. Rehabilitation of the coronary patient. 2nd ed. New York: John Wiley, 1984

Hills M, Armitage P. The two-period cross-over clinical trial. Br J Clin Pharmac 1979; 8: 7-20

Hoffman A, Duba J, Lengyel M, Majerk K. The effect of training on the physical working capacity of MI patients with left ventricular dysfunction. Eur Heart J 1987; 8 (Suppl G): 43-9

Horgan J, Bethell H, Carson P, Davidson C, Julian D, Mayou RA, Nagle R. Working party report on cardiac rehabilitation. Br Heart J 1992; 67: 412-18

Hossack KF, Bruce RA, Clarke LJ., Influence of propanolol on exercise prescriptions of training heart rates. Cardiology 1980; 65: 47-58

Hossack KF, Bruce RA, Green B, Kusumi F, DeRouen TA, Trimble S. Maximal cardiac output during upright exercise: approximate normal standards and variations with coronary heart disease. Am J Cardiol 1980; 46: 204-12

Hughson RL, Weisigner KH, Swanson GD., Blood lactate concentration increases as a continuous function in progressive exercise. J Appl Physiol 1987; 62:1975-81

Hung J, Gordan EP, Houston N, Haskell WL, Goris ML, DeBusk RF. Changes in rest and exercise myocardial perfusion and left ventricular function 3 to 26 weeks after clinically uncomplicated acute myocardial infarction: effects of exercise training. Am J Cardiol 1984; 54; 943-50

Hunt SM, Mc Ewen J, McKenna SP. Measuring health; A guide to rating scales and questionnaires.Oxford: Oxford University Press, 1986

Ignone G, Giordano A, Tavazzi L. Effects of a short-term training programme in post-infarct patients with residual myocardial ischaemia. Eur Heart J 1988; 9 Suppl M(10): 13-21

Jain A, Myers GH, Sapin PM, O'Rouke RA. Comparison of symptom limited and low level exercise tolerance tests early after acute myocardial infarction. J Am Coll Cardiol 1993; 22: 1816-20

Janosi A, Hoffman A, Hankoczy J. Is exercise training harmful after myocardial infarction? Chest 1987; 92: 933-4

Jondeau G, Katz SD, Zohman L, Goldberger M, McCarthy M, Bourdarias J-P, Le Jemtel TH. Active skeletal muscle mass and cardiopulmonary reserve. Circulation 1992; 86: 1351-6

Jorfeldt LS. Measurement of skeletal muscle blood flow in humans; Plethysmographic, bolus and continuous infusion technique. Am J Cardiol 1988; 62 : 25E-29E

Jugdutt BI, Michorowski BL, Kappagoda CT. Exercise training after anterior Q wave myocardial infarction; importance of regional left ventricular function and topography. J Am Coll Cardiol 1988; 12: 362-72

Juneau M, Colles P, Theroux P, de Guise P, Pelleteir G, Lam J, Waters D., Symptom limited versus low level exercise testing before hospital discharge after MI. J Am Coll Cardiol 1992; 20: 927-33

Kaplan RM. Quality of life measurement. In: Karoly P, ed. Measurement strategies in health psychology. New York: J Wiley and Sons, 1985: Chapter 3

Kavanagh T, Shephard RJ, Tuck JAA, Quireshi S. Depression following myocardial infarction. The effects of distance running. Ann NY Acad Sci 1977; 301: 1029-38

Kellerman JJ. The role of exercise therapy in patients with impaired ventricular function and chronic heart failure. J Cardiovascular Pharmacology 1987; 10 (suppl 6): S172-S 177

Kellerman JJ, Shemesh J, Ben-Ari E. Contraindications to physical training in patients with impaired ventricular function. Eur Heart J 1988; 9 (supplement F): 71-6

Kloner RA, Kloner JA. The effect of early exercise on myocardial infarct scar formation. Am Heart J 1983; 106 (5 Pt 1): 1009-13

Koch M, Dougard H, Broustet J-P. The benefit of graded physical exercise in chronic heart failure. Chest 1992; 101 (5 Suppl): 231S-235S

Koike A, Hiroe M, Adachi H, Yajima T, Nogami A, Ito H, Takamotot, Taniguchi K, Marumo F. Anaerobic metabolism as an indicator of aerobic function during exercise in cardiac patients. J Am Coll Cardiol 1992; 20: 120-6

Kolman P, Griffin G, Ward HW. Differences in psychological state between cardiac patients assigned to either an intensive or a minimal exercise program - a randomization effect? Psychosom Med 1984; 46: 75-8.

Ladwig KH, Roll G, Breithardt G, Budde T, Borggrefe M. Post infarction depression and incomplete recovery 6 months after acute myocardial infarction. Lancet 1994; 343: 20-3.

Langosch W. Psychological effects of training in coronary patients: a critical review of the literature. Eur Heart J 1988; 9 Suppl M (10): 37-42

Laslett LJ, Paumer L, Scott-Baier P, Amsterdam EA. Efficacy of exercise training in patients with coronary artery disease who are taking propranolol. Circulation 1983; 68: 1029-34

Lee AP, Ice R, Blessey R, Sanmarco ME. Long term effects of physical training on coronary patients with impaired ventricular function. Circulation 1979; 60: 1519-26

LeJemtel TH, Katz S, Jondeau G, Solomon S. Critical analysis of methods for assessing regional blood flow and their reliability in clinical medicine. Chest 1992 101: 219S-222S

Lerman J, Bruce RA, Sivarajan E, Gladys MA, Pettet EM, Trimble S. Low-level dynamic exercises for earlier cardiac rehabilitation: aerobic and hemodynamic responses. Arch Phys Med Rehabil 1976; 57: 355-60

Levine SA, Lowne F. Armchair treatment of acute coronary thrombosis. JAMA 1952; 148: 1365

Lewin B, Robertson IH, Cay EL, Irvining JB. Effects of self-help post-myocardial infarction rehabilitation on psychological adjustment and use of health services. Lancet 1992; 339: 1036-40

Lindsay DC, Anand IS, Bennett JG, Pepper JR, Yacoub MH, Rothery SM, Severs NJ, Poole-Wilson PA. Ultrastructural analysis of skeletal muscle: microvascular dimensions and basement membrane thickness in chronic heart failure. Eur Heart J 1994; 15: 1470-6

Lindsay C, Jennrich JA, Biemolt M. Programmed instruction booklet for cardiac rehabilitation teaching. Heart and Lung 1991; 20: 648-53

Lindskog BD, Sivarajan ES. A method of evaluation of activity and exercise in a controlled study of early cardiac rehabilitation. J Cardiac Rehab1982; 2: 156-65

Lipkin DP, Scriven AJ, Crake T, Poole-Wilson PA. Six minute walking test for assessing exercise capacity in chronic heart failure. Br Med J 1986; 292: 653-5

Mallory GK, White PD, Salcedo-Salger J. The speed of healing of myocardial infarction: A study of the pathological anatomy of seventy-two cases. Am Heart J 1939; 18: 647-71

Mancini DM, Henson D, LaManca, Levine S. Respiratory muscle function and dyspnea in patients with chronic congestive heart failure. Circulation 1992; 86: 909-18

Massie B, Conway M, Yonge R, Frostick S, Ledingham J, Sleight P, Radda G, Rajagopalan B. Skeletal muscle metabolism in patients with congestive heart failure: relation to clinical severity and blood flow. Circulation 1987; 76: 1009-19

Mathes P. Physical training in patients with ventricular dysfunction: choice and dosage of physical exercise in patients with pump dysfunction. Eur Heart J 1988; 9 Suppl F (2): 67-9

Mayou R, MacMahon D, Sleight P, Florencio MJ. Early rehabilitation after myocardial infarction. Lancet 1981; 2 (8260-61): 1399-1402

McKelvie RS, Teo KK, McCartney N, HumenD, Montague T, Yusuf S. Effects of exercise training in patients with congestive heart failure: a critical review. J Am Coll Cardiol 1995; 25: 789-96

Miller NH, Haskell WL, Berra K, DeBusk RF. Home verus group exercise traing for incresing functional capacity after myocardial infarction. Circulation 1984; 70: 645-9

Minotti JR, Christoph I, Massie BM. Skeletal muscle function, morphology and metabolism in patients with congestive heart failure. Chest 1992; 101 (5 Suppl): 333S-339S

Miranda CP, Froelicher VF. Cardiac Rehabilitation; A review. Euro Rehab 1991; 1: 5-21

Moss AJ, DeCamilla J, Davis H. Cardiac death in the first six months after a myocardial infarction: Potential for mortality reduction in the easrly posthospital period. Am J Cardiol 1977; 39: 816

Muiesan G, Sorbini CA, Solinas E, Grass I, Casucci G, Petz E. Comparison of carbon-dioxide rebreathing and direct Fick methods for detemining cardiac output. J Appl Physiol 1968; 24: 424-9

Muller AF. Studies of central and regional haemodynamic parameters in chronic heart failure [MD Thesis] University of Nottingham 1992

Muller AF, Batin P, Evans S, Hawkins M, Cowley AJ. Regional blood flow in chronic heart failure; the reason for the lack of correlation between patients exercise tolerance and cardiac output. Br Heart J 1992; 67: 478-81

Myers J, Froelicher VF. Predicting outcome in Cardiac Rehabilitation. J Am Coll Cardiol 1990; 15: 983-5

Noble BJ. Clinical applications of perceived exertion. Med Sci Sports Exerc 1982; 14: 406-11

O'Connor GT, Buring JE, Yusuf S, Goldhaber SZ, Olmstead EM, Paffenbarger RS Jr, Hennekens CH. An overview of randomiszed trails of rehabilitation with exercise after myocardial infarction. Circulation 1989 ; 80: 234-44

O'Sullivan SB. Percieved exertion: A review. Phys Ther 1984; 64: 343-6

Oldridge N,Guyatt G, Jones N, Crowe J, Singer J, Feeny D, McKelvie R, Runions J, Striener D, Torrence G. Effects on quality of life with comprehensive rehabilitation after acute myocardial infarction. Am J Cardiol 1991; 67: 1084-9

Oldridge NB, Guyatt GH, Fischer ME, Rimm AA. Cardiac rehabilitation after myocardial infarction. Combined experience of randomized clinical trials. JAMA 1988 ; 260: 945-50

Oldridge NB, Streiner DL. The health belief model: predicting compliance and dropout in cardiac rehabilitation. Med Sci Sports Exerc 1990; 22: 678-83

Ott CR, Sivarajan ES, Newton KM, Almes MJ, Bruce RA, Bergner M, Gilson. A controlled randomised study of early cardiac rehabilitation: The sickness Impact Profile as an assessment tool. Heart and Lung 1983; 12: 162-70

Parmley WW. Position report on cardiac rehabilitation. J Am Coll Cardiol 1986; 7: 451-3

Pashkow FJ. Issues in contemporay Cardiac Rehabilitation: A historical perspective. J Am Coll Cardiol 1993; 21: 822-34

Paterson DH, Shepherd RJ, Cunningham D, Jones NL, Andrew G. Effects of physical training on cardiovascular function following myocardial infarction. J Appl. Physiol 1979; 47: 482-9

Patrick JM, Bassey EJ, Irving JM, Blecher AB, Fentem PH. Objective measurement of customary physical activity in elderly men and women before and after retirement. Q J Exptl Physiol 1986; 71: 47-58

Perk J, Hedback B, Jutterdal S. Cardiac rehabilitation: evaluation of a long term programme of physical training for out-patients. Scand J Rehabil Med 1989; 21: 13-17

Poole-Wilson PA, Buller NP, Lipkin DP. Regional bloodflow, muscle strength and skeletal muscle histology in severe congestive heart failure. Am J Cardiol 1988; 62: 49E-52E

Poole-Wilson PA, Buller NP, Lindsay DC. Blood flow and skeletal muscle in patients with heart failure. Chest 1992: 101 (Suppl): 330S-332S

P. Re. Cor group. Comparison of a rehabilitaion programme, a counselling programme and usual care after an acute myocardial infarction: results of a long-term randomized trial. Eur Heart J 1991; 12: 612-6

Reybrouck T, Fagard R. Assessment of cardiac output at rest and during exercise by a carbon dioxide rebreathing method. Eur Heart J 1990; 11 (Suppl 1): 21-5

Riegel BJ, Dracup KA. Does overprotection cause cardiac invalidism after acute myocardial infarction. Heart and Lung 1992; 21: 529-35

Robergs RA, Chwalbinska-Moneta J, Mitchell JB, Pascoe DD, Houmard J, Costill DL. Blood lactate threshold differences between arterialized and venous blood. Int J Sports Med 1990; 11: 446-51

Roman O, Guttierrez M, Luksic I, Chavez E, Camuzzi AL, Villalon E, Klenner C, Cumsille F. Cardiac rehabilitation after acute myocardial infarction. 9 year controlled follow-up. Cardiol 1983; 70: 223-31

Rozkovec A, Papouchado M, James MA, Kendrick AH, Clarke LM, Rees JR. The relationship of symptoms to performance in paced patients with breathlessness. Eur Heart J 1989; 10: 63-9

Sable DL, Brammell HL, Sheehan MW, Nies AS, Gerber J, Horwitz LD. Attenuation of exercise conditioning by beta-adrenergic blockade. Circulation 1982; 65: 679-83

Saltin B, Blomqvist B, Mitchell JH, Johnson L, Wildenthal K, Chapman CB. Response to submaximal and maximal exercise after bed rest and training. Circulation 1968; 38 (Suppl 7): 1-78

Savin WM, Haskell WL, Houston-Miller N, DeBusk RF. Improvement in aerobic capacity soon after myocardial infarction. J. Cardiac Rehab 1981; 1: 337-42

Silber D, McLaughlin D, Sinoway L. Leg exercise conditioning increases peak forearm bloodflow. J Appl Physiol. 1991; 71: 1568-73

Sinoway LI. Effect of conditioning and deconditioning stimuli on metabolicaly determined blood flow in humans and implications for congestive heart failure. Am J Cardiol 1988; 62: 45E - 48E

Sivarajan ES, Bruce RA, Lindskog BD, Almes MJ, Belanger L, Green B. Treadmill test responses to an early exercise program after myocardial infarction; a randomized study. Circulation 1982; 65: 1420-8

Sivarajan ES, Newton KM,Almes MJ, Kempe TM, Mansfield LW, Bruce RA. Limited effects of out-patient teaching and counselling after myocardial infarction: a controlled study. Heart and Lung 1983; 12; 65-73

Smutok MA, Skrinar GS, Pandolf KB. Exercise intensity: subjective regulation by perceived exertion. Arch Phys Med Rehab 1980; 61: 569-74

Sparks KE, Shaw DK, Eddy D, Hanigosky P, Vantrese J, Alternatives for cardiac rehabilitation patients unable to return to a hospital-based program. Heart and Lung 1993; 22: 298-303

Squires RW, Gau G, Miller TD, Allison TG, Lavie CJ. Cardiovascular rehabilitation: status 1990. Mayo Clin Proc 1990; 65: 731-55

Squires RW, Lavie CJ, Brandt TR, Gau GT, Bailey KR.Cardiac rehabilitation in patients with severe ischaemic left ventricular dysfunction. Mayo Clin Proc 1987; 62: 997-1002

Stern MJ. Psychological rehabilitation following myocardial infarction and coronary artery bypass graft surgery. In Wenger NK and Hellerstein HK eds: Rehabilitation of the coronary patient. 2nd ed. New York: John Wiley and Sons, 1984

Stern MJ, Cleary P. The national exercise and heart disease project: psychological changes observed during a low-level exercise program. Arch Phys Med 1981; 141: 131-7.

Stern MJ, Gorman PA, Kaslow L. The group counselling v exercise therapy study. A controlled intervention with subjects following myocardial infarction. Arch Intern Med 1983; 143: 1719-25

Sullivan MJ, Cobb FR. Central hemodynamic response to exercise in patients with chronic heart failure. Chest 1992; 101 (5 Suppl): 340S-346S

Sullivan MJ, Green HJ, Cobb FR. Altered skeletal muscle metabolic response to exercise in chronic heart failure. Circulation 1991; 84: 1597-1607

Sullivan MJ, Higginbotham MB, Cobb FR. Exercise training in patients with severe left ventricular dysfunction. Circulation 1988; 78: 506-15

Sullivan MJ, Higginbotham MB, Cobb FR. Exercise training in patients with chronic heart failure delays ventilatory anaerobic threshold and improves submaximal exercise performance. Circulation 1989; 79: 324-9

Sumner DS. Mercury strain-gauge plethysmography. In: Bernstein EF; Noninvasive diagnostic techniques in vascular disease. St. Louis: Mosby, 1985: Chapter 15

TakataT, Yamabe H, Fukazaki H. The role of oxygen extraction in peripheral tissues in exercise capacity in chronic heart failure. Jpn J Med 1990; 29: 266-73

Taniguchi K, Itoh H, Yajima T, Doi M, Niwa A, Marumo F. Predischarge early exercise therapy in patients with acute myocardial infarction on the basis of anaerobic threshold. Jpn Circ J 1990; 54: 1419-25

Thompson PD. The benefits and risks of exercise training in patients with chronic coronary artery disease. JAMA 1988; 259: 1537-40

Thow M, Halligan S, Nimmo M. Heart rate monitoring and exercise. Physio Pract 1987; 3: 103-6

Thow M, Newton M. The Gartnavel experience in health promotion 1986. Physio 1990; 76: 2-6

Tonnesen KH. Simultaneous measurement of the calf blood flow by strain-guage plethysmography and the calf muscle blood flow measured by 133Xenon clearance. Scand J Clin Lab Invest 1968; 21: 65-76

Topol EJ, Juni JE, O'Neill WW, Nicklas JM, Shea MJ, Burek K, Pitt B. Exercise testing three days after onset of acute myocardial infarction. Am J Cardiol 1987; 60: 958-62

Ueshima K, Saito M, Shimohara A, Uchimoto S, Kawaguchi M, Fukami K, Sumiyoshi T, Haze K, Hiramori K. Management and evaluation of non-supervised home exercise program in a convalescent phase of acute myocardial infarction. Jpn Circ J 1990; 54: 1437-42

Uren N, Lipkin DP. Exercise training as therapy for chronic heart failure. Br Heart J 1992; 67: 430-3

Volterrani M, Clark AL, Ludman PF, Swan JW, Adamopoulos S, Piepoli M, Coats AJS. Predictors of exercise capacity in chronic heart failure. Eur Heart J 1994; 15: 801-9

Walsh JT, Andrews RA, Evans A, Cowley AJ. Failure of "effective" treatment for heart failure to improve normal customary activity. Br Heart J 1995; 74: 373-6

Wasserman K. Reduced aerobic enzyme activity in skeletal muscles of patients with heart failure. Circulation 1991; 84: 1868-70

Wasserman K, Beaver WL, Whipp BJ. Gas exchange theory and the lactic acidosis (anaerobic) threshold. Circulation 1990; 81 (Suppl 1):II 14-30

Wenger NK, Mattson ME, Furberg CD, Elinson J. Assessment of the quality of life in clinical trials of cardiovascular therapies. Am J Cardiol 1984; 54: 908-13

West RR, Evans DA. Lifestyle changes in long term survivors of acute myocardial infarction. J. Epidem and Comm Health 1986 ; 40: 103-9

Whitney RJ. The measurement of volume changes in human limbs. J Physiol 1953; 121: 1-27

Wiener DH, Fink LI, Maris J, Jones RA, Chance B, Wilson JR. Abnormal skeletal muscle bioenergetics during exercise in patients with heart failure: role of reduced muscle blood flow. Circulation 1986; 73: 1127-36

Wiklund I, Sanne H, Vedin A, Wilhelmsson C. Sick-role and attitude towards disease and working life two months after myocardial infarction. Scand J Rehab 1984; 16: 57-64

Williams JG, Eston RG. Determination of the Intensity Dimension in Vigorous Exercise Programmes with particular reference to the use of the RPE. Sports Med 1989; 8: 177-89

Wilson JR, Mancini DM, Dunkman WB. Exertional fatigue due to skeletal muscle dysfunction in patients with heart failure. Circulation 1993; 87: 470-5

Wilson JR, Martin JL, Schwartz D, Ferraro N., Exercise intolerance in patients with chronic heart failure: role of impaired nutritive flow to skeletal muscle. Circulation 1984; 69: 1079-87

Wood-Dauphine SL, Opzoomer MA, Williams JI, Marchand B, Spitzer WO. Assessment of global function; the Reintegration to Normal Living index. Arch Phys Med Rehabil 1988; 69: 583-90.

Worcester MC, Hare DL, Oliver RG, Reid MA, Goble AJ., Early programmes of high and low intensity exercise and quality of life after acute myocardial infarction. Br Med J. 1993; 307: 1244-7

Yeh MP, Gardner RM, Adams TD, Yanowitz FG, Crapo RO. "Anaerobic threshold": problems of determination and validation. J Appl Physiol 1983; 55: 1178-86

Zelis R, Longhurst J, Capone RJ, Mason DT. A comparison of regional blood flow and oxygen utilization during dynamic forearm exercise in normal subjects and patients with congestive heart failure. Circulation 1974; 50: 137-43

Zelis R, Sinoway LI, Musch TI. Why do patients with congestive heart failure stop exercising. J Am Coll Cardiol 1988; 12: 359-61

Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychia Scand 1983; 67: 361-70

APPENDIX A

Activity Summary Questionnaire

ACTIVITY SUMMARY QUESTIONNAIRE

Week of ____________ to ______________ Name_______________

As a participant in the Cardiac Rehabilitation Project your help is needed in providing us with information about how much activity you are now doing. Try to estimate the average number of minutes you spent on each activity in a day. In the next column, write down how many days you did that activity this week. Include even those activities you did only once or twice. You may not be doing very activity, so put a 0 next to those you did not do this week. Where it says "specify", tell exactly what you did.

ACTIVITY	Approximate No. Min per day	Days per week
1. Walking (shopping, doing errand, etc.)		
2. Walking for exercise		
distance		
time		
3. Climbing stairs		
number of steps *(floors)*		
how often each day		
4. Exercises *(Callisthenics)* (please specify)		
5. Housekeeping		
light (dishes, dusting, sweeping, etc.)		
heavy (laundry, mopping, ironing etc.)		
6. Visiting		
at-home visitors		
visiting away (parties, cinema, movies, friends, etc.)		
7. Sports/ Recreation (please specify)		
(golf, bowling, sailing, cycling, etc.)		
8. Gardening		
light (weeding, planting, etc.)		
heavy (pushing mower, digging, hoeing, etc.)		
9. Hobbies (please specify)		
10. Driving a car		
11. Repair and maintenance		
light (*basic tune-up*, fixing appliances)		
heavy (woodworking, plumbing, painting etc.)		

12. If not retired, have you returned to work? No__ Yes__
If yes, Full time_____ Part time_____ hours per week____
13. Have you resumed sexual activity? Yes____ No____
14. Other activities (please specify)
15. Was this more or less activity than last week?
16. If different from last week, what was the reason?

METHOD OF CODING

Q.1. Walking was combined with Q.6 to determine when outdoor activities were initiated.

Q.2. Walking for exercise was coded:

1. Maximum distance walked continuously at least three days per week in eighths of a mile.
2. Time required (in minutes) for maximum distance
3. Total distance walked in a day at least three days per week in eighths of a mile
4. Minutes walked per day for total distance
5. Number of walks per day for total distance
6. Total distance walked per week in miles
7. Number of days walked per week.

Q.3. Number of stairs climbed (22 steps) per day was coded:

1. Increments: 0= 0-1; 1=1-1.9 etc.
2. Number of times (sessions) per day.
3. Number of days per week.

Q.4. Callisthenics were coded

1. Yes/no/unknown
2. Number of callisthenics done per session
3. Minutes per day
4. Days per week

Q.5. Light and heavy housekeeping were coded by first week of return to MET level of function before myocardial infarction:

1. Code	0 = no activity	5 = MET 4-5
	1 = MET 1.5	6 = MET 5-6
	2 = MET 2.2	7 = MET 6-7
	3 = MET 2-3	8 = MET 7-8
	4 = MET 3-4	10 = MET >9

2. Minutes per day
3. Days per week

Q.6. Visiting was coded:

0 = none
1 = home
2 = away
3 = home/away
4 = unspecified

Q.7. Sports and Recreation (see coding for Q 5)

Q.8. Gardening (see coding for Q 5)

Q.9. Hobbies could not be coded in METs

Q.10. Driving was coded by first week of return

Q.11. Repair and maintenance (see coding for Q 5)

Q.12. Return to work was coded by week of return:

1. 0 = retired before myocardial infarction
   1 = no
   2 = part-time work
   3 = full time
2. Hours worked per week.

Q.13. Resumed sexual activity was coded by week of return

0 = no partner
1 = no
2 = yes

Q.14. Change in activity from preceding week was coded

1. 1 = less
   2 = same
   3 = more
2. Reasons for less activity
   1 = health (cardiac)
   2 = health (non-cardiac)
   3 = health (unspecified)
   4 = in hospital
   5 = out of hospital
   6 = vacation or travel
   7 = return to work
   8 = weather
   9 = change in activity
   10 = change in exercise
3. Reasons for more activity
   1 = health (cardiac)
   2 = health (non-cardiac)
   3 = health (unspecified)
   4 = doctors advice
   5 = out of hospital
   6 = vacation or travel
   7 = return to work
   8 = weather
   9 = change in activity
   10 = change in exercise
   11 = stress

APPENDIX B

Original form of Edinburgh Rehabilitation Status Scale (ERSS)

EDINBURGH REHABILITATION STATUS SCALE (ERSS)

I. SUPPORT SUBSCALE.

0 = Independent. May have aids or appliances, or has successfully used an adapted house. Not requiring any help from spouse, relatives or friends. Responsible for own medication and self-care irrespective of standard achieved.

1 = Intermittently dependent. Usually independent but occasionally has had help within the time scale - irregularly or at patients initiative.

2 = Intermediate grade.

3 = Supported by relatives or friends. Needs help of others with aids or in other ways. Lives in own home or supported accommodation with the understanding that he/she can cope with some domestic and economic responsibilities. Regular visits from professionals and/or other arranged contacts may be needed. Relatives may provide an unusual amount of support but this will be at long time-intervals. When alone, he/she will be able to make a hot drink and answer the door and telephone.

4 = Intermediate grade.

5 = Provided with essential supervision, i.e. for toilet, moving around the house etc. This may be in a residential home, or at home with a relative or other person who carries the overall domestic responsibilities and perhaps shares such monitoring with staff, where, for example the patient attends a Day Centre.

6 = Intermediate grade.

7 = In hospital or at home having full nursing monitoring and care.

II. INACTIVITY SUBSCALE.

0 = Within the time-scale has consistently undertaken, effectively and without difficulty, the physical and mental tasks involved in occupational, domestic and leisure purposes.

1 = Intermittently inactive or occasionally ineffective. Usually active but occasionally within the time-scale has needed or taken time off work or failed to maintain non-work

activities e.g. self-care which is usually accomplished and/or pastimes or interests.

2 = Intermediate grade.

3 = Modified activity. Effectiveness is impaired. Levels of activities have been modified by making them less responsible or reduced in time or at a more leisurely pace. May have a sympathetic employer, special arrangements or sheltered employment. Household work and leisure activities similarly modified.

4 = Intermediate grade.

5 = Limited activities. Inefficient or needs to have arrangements made or needs encouragement to sustain tasks or routine activities. Leisure activities similarly restricted.

6 = Intermediate grade.

7 = Very restricted or very ineffective. Unoccupied or essentially inactive. Cannot sustain purposeful activities.

III. <u>SOCIAL INTEGRATION/ISOLATION SCALE.</u>

0 = Within the time-scale period he/she has interacted frequently, competently and appropriately with a varied range of people.

1 = Occasional difficulties. Intermittent problems in social integration. In certain situations fails to participate; or fails to produce the appropriate social response; or may avoid or reject or be rejected from some substained or intimate relationships.

2 = Intermediate grade.

3 = Noticeably limited participation. Impairments limit social integration or impose disadvantages by restricting contacts or making personal relationships difficult. Participation may be restricted to family and old friends and to people in certain special situations. Psychological impairments may show a failure to deal adequately with everyday social encounters, avoidance of new contacts or very superficial participation.

4 = Intermediate grade.

5 = Severely restricted contacts and relationships. has dealt with certain few individuals only, or may be

uncommunicative, unresponsive, intermittently disruptive or otherwise socially incompetent.

6 = Intermediate grade.

7 = Very isolated and/or almost constantly alienated.

IV. <u>EFFECTS OF CURRENT SYMPTOMS SUBSCALE.</u>

0 = Symptom free within the time-scale. this level is given even if a simple drug regime is required to maintain it.

1 = Occasional or mild symptoms. Medications may be onerous and/or aids or appliances though unobtrusive may impinge on freedom.

2 = Intermediate grade.

3 = Noticeable but moderate effects of symptoms/ signs within the time-scale. Clinical assessment revels moderate effects of dysfunction. Evidence of patient role is noticeable to friends and acquaintances. However the patients daily routine is accomplished without too much difficulty though work or leisure may be interrupted by treatment, need to adjust appliances etc.

4 = Intermediate grade.

5 = Obviously severe symptoms. The symptom effects are constant or nearly so and they will often be disturbing or distressing to the patient and his/her carers. These effects will be seen by others as they will obviously interfere with the patients lifestyle. In spite of this he/she manages to co-operate in an agreed regime, probably with difficulty.

6 = Intermediate grade.

7 = Incapacitated . Life pattern is determined almost entirely by symptoms and/or medical or nursing needs.

APPENDIX C

Modified form of ERSS used in early rehabilitation study.

LIFE STYLE QUESTIONNAIRE

This questionnaire looks at four aspects of your lifestyle .

For each of the sections please tick the statement (i,ii,iii,or iv) that most closely resembled your situation over the past seven days.

A.Support.

i) Independent.
   Did not require any help from partner, relatives or friends.
   Able to administer own medication and domestic/self care.

ii) Mainly independent but occasionally needed to ask for help with domestic/self care.

iii) Required help for most of past seven days.

iv) Needed help with domestic/self care for part of each day over past seven days.

B.Activity.

i) Consistently performed occupational, domestic and leisure activities without difficulty.

ii) Usually active but occasionally within past seven days needed to take time off work/domestic activity or unable to continue with past-times or interests.

iii) Activity level reduced but able to function effectively.

iv) Effectiveness impaired. Needed to modify activities by reducing the level of responsibility, length of time or perform at a more leisurely pace.

C.Social.

i) Participated in social activities over past seven days without any difficulty.

ii) Experienced occasional difficulties in socialising with people, i.e. did not wish to participate;avoided some long term friends. Preferred to maintain contact via telephone/letters.

iii) Frequently experienced difficulties in socialising with people.

iv) Restricted social participation to relatives/old friends. Avoided new contacts.

D.Symptoms.

i) Remained symptom free throughout past seven days.

ii) Experienced occasional or mild symptoms.

iii) Intermittent symptoms caused moderate but noticeable effect.

iv) Persistent symptoms caused moderate but noticeable effect.
Able to accomplish daily routine without much difficulty.

Coding for lifestyle Questionnaire.

In all sections:-

i)	Score = 1	iii)	Score = 3
ii)	Score = 2	iv)	Score = 4

APPENDIX D

Hospital anxiety and depression (HAD) questionnaire

QUESTIONNAIRE.

This questionnaire is designed to help us know how you feel.

Read each question and underline the reply which comes closest to how you have been feeling over the past few days.

At the end you should have underlined fourteen replies.

Don't take too long over your replies: your immediate reaction to each item will probably be more accurate than a long thought out response.

(Scoring - not available to patient)

1) I feel tense or 'wound up':

Most of the day	3
A lot of the time	2
From time to time, occasionally	1
Not at all	0

2) I still enjoy the things I used to enjoy:

Definitely as much	0
Not quite as much	1
Only a little	2
Hardly at all	3

3) I get a sort of frightened feeling as if something awful is about to happen:

Very definitely and quite badly	3
Yes, but not too badly	2
A little, but it does not worry me	1
Not at all	0

4) I can laugh and see the funny side of things:

As much as I always could	0
Not quite so much now	1
Definitely not so much now	2
Not at all	3

5) Worrying thoughts go through my head:

A great deal of the time	3
A lot of the time	2
From time to time but not often	1
Only occasionally	0

6) I feel cheerful:

Not at all	3
Not often	2
Sometimes	1
Most of the time	0

7) I can sit at ease and feel relaxed:

Definitely	0
Usually	1
Not often	2
Not at all	3

8) I feel as I am slowed down:

Nearly all the time	3
Very often	2
Sometimes	1
Not at all	0

9) I get a sort of frightened feeling like 'butterflies' in the stomach:

Not at all	0
Occasionally	1
Quite often	2
Very often	3

10) I have lost interest in my appearance:

Definitely	3
I don't take as much care as I should	2
I may not take quite as much care	1
I take just as much care as ever	0

11) I feel restless as if I have to be on the move:

Very much indeed	3
Quite a lot	2
Not very much	1
Not at all	0

12) I look forward with enjoyment to things:

As much as I ever did	0
Rather less than I used to	1
Definitely less than I used to	2
Hardly at all	3

13) I get sudden feelings of panic:

Very often indeed	3
Quite often	2
Not very often	1
Not at all	0

14) I can often enjoy a good book or radio or TV programme:

Often	0
Sometimes	1
Not often	2
Very seldom	3

Anxiety and depression questions are listed alternately, starting with anxiety.

Scores above 11 for depression questions indicate clinical depression.

APPENDIX E

Quality of life questionnaire

used in chronic heart failure study

1. In the last two weeks how much of the day time have you had to spend in bed because of poor health?

	Code
Nearly all of the time	1
Most of the time	2
A good bit of the time	3
Some of the time	4
A little bit of the time	5
Hardly any of the time	6
None of the time	7

2. In the last two weeks how much of the day have you had to spend just sitting in a chair because of poor health?

Nearly all of the time	1
Most of the time	2
A good bit of the time	3
Some of the time	4
A little bit of the time	5
Hardly any of the time	6
None of the time	7

3. In the last 2 weeks has poor health stopped you walking outside even when the weather has been good?

I hardly ever walk outside at all	1
I hardly ever walk outside any further than my garden	2
Sometimes I feel well enough to walk outside further than my garden	3
A good bit of the time I feel well enough to walk outside further than my garden	4
Most of the time I feel well enough to walk outside further than my garden	5
Nearly all of the time I feel well enough to walk outside further than my garden	6
My health does not stop me walking outside whenever I want	7

4. In the last 2 weeks how have you been able to get around your home and neighbourhood compared to a month ago?

With much more ease	7
With more ease	6
With a bit more ease	5

With the same amount of ease	4
With a bit less ease	3
With less ease	2
With much less ease	1

5. If you had tried to go out walking on the flat during the last 2 weeks, how tired and/or breathless do you think you would have been?

Extremely short of breath and /or extremely tired	1
Very short of breath and/or very tired	2
Quite a bit short of breath and/or quite a bit of tiredness	3
Moderate shortness of breath and/or moderately tired	4
Some shortness of breath and/or somewhat tired	5
A little short of breath and/or a little tired	6
Not at all short of breath and not at all tired	7

6. If you tried to walk uphill in the last 2 weeks, how tired and/or short of breath do you think you would have been?

Extremely short of breath and /or extremely tired	1
Very short of breath and/or very tired	2
Quite a bit short of breath and/or quite a bit of tiredness	3
Moderate shortness of breath and/or moderately tired	4
Some shortness of breath and/or somewhat tired	5
A little short of breath and/or a little tired	6
Not at all short of breath and not at all tired	7

7. If you had tried to climb the stairs in the last 2 weeks, how tired and/or short of breath do you think you would have been?

Extremely short of breath and /or extremely tired	1
Very short of breath and/or very tired	2
Quite a bit short of breath and/or quite a bit of tiredness	3
Moderate shortness of breath and/or moderately tired	4
Some shortness of breath and/or somewhat tired	5
A little short of breath and/or a little tired	6
Not at all short of breath and not at all tired	7

8. If you had tried to go out walking in the last two weeks, do you think you would have needed to keep stopping to rest?

I am not well enough to walk at all	1
I would need to rest very many times	2
I would need to rest many times	3

I would need to rest quite often	4
I would need to rest just a few times	5
I would hardly ever need to rest	6
I would not have to rest at all	7

9. In the last 2 weeks has there been any change in the amount of walking you can do compared with a month ago? (Assume the weather has been suitable for walking over the past month)

I am able to do much more walking	7
I am able to do more walking	6
I am able to do a bit more walking	5
I am able to do the same amount of walking	4
I am able to do a bit less walking	3
I am able to do less walking	2
I am able to do much less walking	1

10. In the last 2 weeks how do you think you would have felt if you had tried to do heavy work around the house and garden, for example scrubbing floors, digging the garden, moving heavy furniture, decorating, shopping?

Extremely short of breath	1
Very short of breath and/or tired	2
Quite short of breath and/or quite a bit of tiredness	3
Moderate shortness of breath and/or moderately tired	4
Some shortness of breath and/or somewhat tired	5
A little short of breath and/or a little tired	6
Not at all short of breath and not at all tired	7

11. In the last two weeks ho w do you think you would have felt if you had tried to do moderately heavy work around the house and garden, for example vacuum cleaning, ironing, moving chairs and tables, mowing the lawn with a power mower?

Extremely short of breath	1
Very short of breath and/or tired	2
Quite short of breath and/or quite a bit of tiredness	3
Moderate shortness of breath and/or moderately tired	4
Some shortness of breath and/or somewhat tired	5
A little short of breath and/or a little tired	6
Not at all short of breath and not at all tired	7

12. In the last 2 weeks how do you think you would have felt if you had tried to do light work around the house and garden, for example washing dishes, dusting, household repairs, pottering in the garden?

Extremely short of breath	1
Very short of breath and/or tired	2
Quite short of breath and/or quite a bit of tiredness	3
Moderate shortness of breath and/or moderately tired	4
Some shortness of breath and/or somewhat tired	5
A little short of breath and/or a little tired	6
Not at all short of breath and not at all tired	7

13. If you had tried to do jobs around the house and garden in the last 2 weeks, do you think you would have needed to keep stopping to rest?

I need to rest all the time	1
I would have needed to rest very many times	2
I would have needed to rest many times	3
I would have needed to rest quite often	4
I would have needed to rest a few times	5
I would hardly ever have needed to rest	6
I would never have needed to rest	7

14. If you had tried to do jobs around the house and garden in the last 2 weeks, do you think you would have done them more slowly because of your health than other people of your age?

I do things extremely slowly	1
I do things very slowly	2
I do things rather slowly	3
I do things moderately slowly	4
I am a bit on the slow side	5
I do things at the same speed as other people of my age	6
I do things faster than other people of my age	7

15. In the last 2 weeks have you been well enough to follow any of your interests or hobbies?

I cannot follow any interests or hobbies at all because of my state of health	1
I have many interests or hobbies which I would like to follow but cannot because of my state of health	2
I have some interests or hobbies which I would like to follow but cannot because of my state of health	3

I have interests or hobbies which I cannot do as often or as well as I would like because of my state of health	4
I can follow all my interests or hobbies in the same way as I always have but I find I enjoy things less because of my state of health	5
I can follow and enjoy all the hobbies or interests that I want to follow	6
I have been able to take up interests I have not been able to follow for a long time, or taken up new interests because my health has improved	7

16. In the last 2 weeks would you have felt well enough to visit friends and relatives or have friends and relatives round to your house, if you had wanted?

Always	7
Usually	6
Often	5
Sometimes	4
Occasionally	3
Hardly ever	2
Never	1

17. In the last 2 weeks has your health stopped you going out with friends and family, for example to the pub, restaurants, theatre, cinema, sporting events?

Always	1
Usually	2
Often	3
Sometimes	4
Occasionally	5
Hardly ever	6
Never	7

18. In the last 2 weeks have you been able to do more of any social activity that you enjoy, compared with a month ago, because of a change in your health?

I have been able to do less	1
There has been no change in my social life	2
I have been able to do slightly more	3
I have been able to do somewhat more	4

I have been able to do quite a bit more	5
I have been able to do a lot more	6
I have been able to do very much more	7

19. In the last 2 weeks have you had problems with your sex life because of your health?

Extremely so	1
Very much so	2
Quite a bit so	3
Moderately so	4
Somewhat so	5
A little bit so	6
Not at all	7

20. In the last two weeks has your daily life been full of things that are interesting to you?

Nearly all the time	7
Most of the time	6
A good bit of the time	5
Some of the time	4
A little bit of the time	3
Hardly any of the time	2
None of the time	1

21. In the last two weeks have you felt depressed or low in spirits?

Extremely so	1
Very much so	2
Quite a bit so	3
Moderately so	4
Somewhat so	5
A little bit so	6
Not at all	7

22. In the last 2 weeks have you felt concerned, worried or had any fears about your health?

Extremely so	1
Very much so	2
Quite a bit so	3
Moderately so	4
Somewhat so	5

A little bit so	6
Not at all	7

23. In the last two weeks have you been irritable or bad tempered?

I have been very irritable or bad tempered all the time	1
I have been irritable or bad tempered most of the time	2
I have been irritable or bad tempered quite often	3
I have sometimes been irritable or bad tempered	4
I have occasionally been irritable or bad tempered	5
I have been irritable or bad tempered rarely	6
I have not been irritable or bad tempered	7

24. In the last 2 weeks have you been worried by forgetfulness absent-mindedness or poor memory?

Extremely so	1
Very much so	2
Quite a bit so	3
Moderately so	4
Somewhat so	5
A little bit so	6
Not at all	7

25. In the last two weeks how have you felt in your self?

I have felt terrible nearly all the time	1
I have felt poorly most of the time	2
I have felt poorly a good bit of the time	3
I have felt poorly some of the time	4
I have felt quite well a good bit of the time	5
I have felt well most of the time	6
I have felt very well indeed nearly all the time	7

26. In the last 2 weeks have you felt vigorous, energetic and full of life?

I have felt full of energy almost all the time	7
I have felt energetic most of the time	6
I have felt moderately energetic most of the time	5
My energy level varied from time to time but generally I have been fairly lively	4
My energy level varied from time to time but generally I have been on the tired side	3

I have felt lacking in energy most of the time 2
I have had hardly any energy at all 1

27. In the last 2 weeks how breathless have you been?

I have been extremely breathless 1
I have had a very bad fortnight, as far as breathing is concerned 2
I have had rather a bad fortnight, as far as breathing is concerned 3
My breathing has not been too bad 4
My breathing has been quite good 5
I have been only slightly short of breath 6
I have not been short of breath at all 7

28. In the last 2 weeks have you had problems with your breathing during the night?

Every night 1
Nearly every night 2
Most nights 3
Some night 4
A few nights 5
Hardly any nights 6
No nights 7

29. In the past 2 weeks how tired did you feel when you tried to carry out your daily activities?

Extremely tired 1
Very tired 2
Quite a bit tired 3
Moderately tired 4
Somewhat tired 5
A little tired 6
Not at all tired 7

30. In the last 2 weeks how have you felt compared to a month ago?

Much better 7
Better 6
A little better 5
The same 4
A little worse 3

Worse	2
Much worse	1

SECTIONS

Q 1-4	Mobility	15-20	Social
Q 5-9	Activity	21-24	Emotional
Q 10-14	Home management	25-30	Symptoms

APPENDIX F

Patient instructions for use of activity monitor

Using the Activity Monitor

Thank you for agreeing to wear these shoes which will monitor how active you have been during the week.

Please wear the shoes whenever possible whilst undertaking your normal daily activities. Do ensure the laces are **tied tightly,** otherwise the counting device will not function accurately.

Do not wash, clean or polish the shoes as the 'static' created will affect the electronics.

CHARGING THE LEFT SHOE

In order for the shoe to collect and retain information the battery needs to be recharged daily even if you have not worn the shoe that day. **Failure to do this will mean the information will be lost.**

Please charge the shoe for approximately **8 hours** (DO NOT charge for more than 10 hours or the battery will be destroyed). Charging overnight will mean that it is ready for the next day.

Always ensure the charger is turned off at the mains socket before connecting and disconnecting the lead from the charger into the heel. If the charger is working a small red light should be illuminated on the top of the unit. If this does not light up then the unit is not charging the shoe; if this happens please contact the lab early the following morning for further advice.

DIARY OF WEAR

In cast the shoe fails to operate correctly it would be useful to us if we had some indication of when you wore the shoes. We would like you to note when you put the shoes on and took them off during each day.